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DEPARTMENTS OF LABOR AND HEALTH, EDUCATION,
AND WELFARE APPROPRIATIONS FOR 1963

HEARINGS
BEFORE A
SUBCOMMITTEE OF THE
COMMITTEE ON APPROPRIATIONS
HOUSE OF REPRESENTATIVES
EIGHTY-SEVENTH CONGRESS
SECOND SESSION

SUBCOMMITTEE ON DEPARTMENTS OF LABOR AND HEALTH, EDUCATION, AND
WELFARE AND RELATED AGENCIES APPROPRIATIONS

JOHN E. FOGARTY, Rhode Island, *Chairman*

WINFIELD K. DENTON, Indiana

FRED MARSHALL, Minnesota

MELVIN E. LAIRD, Wisconsin

ROBERT H. MICHEL, Illinois

ROBERT M. MOYER, *Staff Assistant to Subcommittee*

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
PART 4

Report on Manpower for Medical Research

Printed for the use of the Committee on Appropriations



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AND WELFARE APPROPRIATIONS FOR 1963.**

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LETTER OF TRANSMITTAL

HON. JOHN E. FOGARTY,
*Chairman, Subcommittee on Departments of Labor and Health, Education, and
Welfare, and Related Agencies Appropriations of the Committee on Approp-
riations, House of Representatives, Washington, D.C.*

DEAR MR. FOGARTY: The report of the Committee on Appropriations accompanying the bill for 1962 appropriations to the National Institutes of Health (Rept. No. 392 on H.R. 7035, 87th Cong., 1st sess.) expressed concern as to the adequacy of the Nation's medical research manpower and requested NIH to prepare a document on manpower requirements. The committee report stated:

"No convincing evidence was submitted which would indicate that the present levels of the research training programs are sufficient to assure the country of a steady and adequate supply of highly qualified research manpower in each of the important—and especially in the rapidly growing—scientific and interdisciplinary areas relevant to medical research. The committee therefore requests that the NIH prepare, before next year's appropriation hearings, a balancesheet of estimated research manpower requirements 5 and 10 years hence and a projection of expected output."

Accordingly, the National Institutes of Health, a constituent of the Public Health Service, U.S. Department of Health, Education, and Welfare, investigated the medical research manpower requirements and resources of the Nation and made projections for the years 1965-70. A report of the findings of this study, prepared by the Resources Analysis Section of the Office of Program Planning, NIH, is transmitted herewith.

The study indicates that an expansion of national expenditures for medical research to a projected level of \$3 billion for 1970 will require a doubling of competent personnel and a greatly accelerated provision of health research facilities and equipment.

Moreover, such increases in essential research manpower—physicians, scientists, and supportive workers—will not be forthcoming unless private and governmental activities aimed at enlarging the total pool of scientific and professional manpower are rapidly expanded.

In these conclusions, the study corroborates other distinguished and highly qualified groups, private as well as public, which have advocated an intensive development of biomedical research resources.

Respectfully submitted.

JAMES A. SHANNON, M.D.,
Director, National Institutes of Health.

MANPOWER FOR MEDICAL RESEARCH

Requirements and Resources, 1965-1970

A Report for the
Subcommittee on Departments of Labor and
Health, Education, and Welfare, and
Related Agencies Appropriations

of the

Committee on Appropriations
House of Representatives

by the

National Institutes of Health

February 1962

Prepared by Resources Analysis Section, Office of Program Planning, National Institutes of Health

Public Health Service
U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

TABLE OF CONTENTS

	<u>Page</u>
<u>SUMMARY</u>	xi
I. INTRODUCTION.....	1
II. THE FUTURE GROWTH OF MEDICAL RESEARCH.....	3
III. SCIENTIFIC MANPOWER ENGAGED IN MEDICAL AND HEALTH-RELATED RESEARCH, 1954-1960.....	9
A. Trends in Employment of Scientific and Professional Manpower in Medical and Health-Related Research, 1954-1960.....	13
Summary.....	22
B. Professional Workers Engaged in Medical and Health-Related Research in 1960.....	23
Summary.....	28
IV. MANPOWER REQUIREMENTS TO MEET THE FUTURE GROWTH OF MEDICAL RESEARCH.....	29
A. Expenditures per Professional Worker in Medical Research, 1954-1960.....	30
B. Projections of Expenditures per Professional Worker, 1961-1970.....	33
Future Manpower Requirements for Medical Research, 1970....	36
Summary.....	37
C. Distribution of Manpower Requirements for the Future.....	38
D. Sources of Supply to Meet Net Requirements for 1970.....	44

TABLE OF CONTENTS

	<u>Page</u>
V. THE FLOW OF PROFESSIONAL WORKERS INTO THE MEDICAL RESEARCH MANPOWER POOL, 1961-1970.....	47
A. Trends in M.D. Participation in Medical and Health-Related Research.....	50
B. The Flow of M.D.'s into the Medical Research Manpower Pool, 1961-1970.....	54
The Flow of M.D.'s into Research, 1961-1970.....	55
Staffing of New Medical Schools.....	58
Impact upon the Total Supply of Physicians to Meet the Health Needs of the Nation.....	61
C. Input of D.O.'s, D.D.S.'s, and D.V.M.'s into the Medical Research Manpower Pool.....	63
D. Participation of Ph.D.'s in the Biosciences and Psychology in Medical and Health-Related Research.....	64
E. The Flow of Ph.D.'s in the Basic Medical Sciences into the Medical Research Manpower Pool, 1961-1970.....	71
F. The Flow of Ph.D.'s in Psychology into the Medical Research Manpower Pool, 1961-1970.....	74
G. Input of Ph.D.'s in Other Science Fields into Medical Research Manpower Pool, 1961-1970.....	76
H. Impact of Rising Participation of Ph.D.'s in Research upon the Educational Process.....	79
I. Assessment of Less than Doctoral Manpower Requirements.	82
J. The Probable Balance.....	83
K. Some Qualifying Observations on the Estimate of M.D.'s and Ph.D.'s Entering Medical Research, 1961-1970.....	84

TABLE OF CONTENTS

	<u>Page</u>
VI. THE OUTLOOK FOR OUTPUT OF M.D.'s and Ph.D.'s, 1961-1970.....	87
A. The Resource Base for Future Growth, 1960-1970.....	87
Population Base Will Expand.....	88
College Enrollment Will Rise.....	92
Graduate Enrollment in the Sciences Will Expand.....	95
B. Output of M.D.'s and Ph.D.'s, 1946-1960, and Projections to 1970.....	100
M.D. Output, 1946-1960, and Projections to 1970.....	102
Ph.D. Output, 1946-1960 and Projections to 1970.....	104
Summary.....	112
VII. IMPLICATIONS FOR NATIONAL POLICY.....	113
APPENDIX A GROWTH IN THE NATION'S EXPENDITURES FOR MEDICAL RESEARCH AND THE OUTLOOK FOR THE FUTURE.....	116
List of Appendix Tables.....	151

LIST OF TABLES

<u>Table No.</u>	<u>Title</u>	<u>Page No.</u>
1	The Nation's Expenditures for Medical and Health-Related Research, 1950-1961	3
2	Scientific and Professional Manpower Engaged in Medical and Health-Related Research by Sector, 1954, 1958 and 1960	15
3	Percent Distribution of Increase in Scientific and Professional Manpower Engaged in Medical and Health-Related Research by Sector, 1954-1960 and 1958-1960	15
4	Number and Full-time Equivalent of Scientific and Professional Manpower Engaged in Medical and Health-Related Research, 1954, 1958 and 1960	16
5	Percent Distribution of Full-time Equivalent of Scientific and Professional Manpower Engaged in Medical and Health-Related Research, 1954, 1958 and 1960	16
6	Scientific and Professional Manpower Engaged in Medical and Health-Related Research by Level of Training, 1958 and 1960	18
7	Percentage Distribution of Increase in Scientific and Professional Manpower Engaged in Medical and Health-Related Research by Level of Training, 1958-1960	18
8	Distribution of NIH First-time Grantees by Level of Training	20
9	Scientific and Professional Personnel Engaged in Medical and Health-Related Research by Field, 1954, 1958 and 1960	21
10	Number and Percentage Distribution of Scientific and Professional Manpower Engaged in Medical and Health-Related Research, 1960	24
11	Number and Percent Distribution of Scientific and Professional Manpower Engaged in Medical and Health-Related Research by Sector and Field, 1960	26

List of Tables

<u>Table No.</u>	<u>Title</u>	<u>Page No.</u>
12	Relation Between Estimated Number and Full-time Equivalents of Scientific and Professional Manpower Engaged in Medical and Health-Related Research in Universities and Research Institutes by Level of Training, 1960	27
13	Comparison of Scientific and Professional Manpower in All Research and Development and in Medical and Health-Related Research, 1954-1958	31
14	Expenditures per Professional Worker in Medical Research and Rate of Increase, 1954-1960, Expressed in Current and Constant Dollars	33
15	Professional Workers Engaged in Medical and Health-Related Research by Sector, 1960; and Estimated Distribution for 1970	39
16	Professional Workers Engaged in Medical and Health-Related Research by Level of Training, 1960, and Requirements for 1970	41
17	Professional Workers Engaged in Medical and Health-Related Research by Field, 1960, and Estimated Distribution for 1970	43
18	Net Manpower Requirements for 1970, Taking into Account Estimated Attrition Through Death, Retirement, and Movement into Other Activities.	45
19	Career Plans of Interns from Selected High and Low Research Emphasis Schools	53
20	Model for Illustrating Flow of M.D.'s Entering Medical Research Manpower Pool, 1955-1979, from Classes of 1950, 1955, 1960 and 1965	56
21	Output of D.O.'s, D.D.S.'s and D.V.M.'s from U.S. Schools, Five-Year Intervals, 1946-1960, and Projections to 1970	63
22	Distribution of Ph.D.'s in Biosciences and Psychology, by Discipline, 1960	65

List of Tables

<u>Table No.</u>	<u>Title</u>	<u>Page No.</u>
23	Ph.D. Bioscientists and Psychologists Whose Primary or Secondary Activity is Research, 1960	66
24	Percent Distribution of Ph.D.'s in the Biosciences and Psychology by Discipline and Type of Employer, 1960	68
25	Model for Illustrating Flow of Ph.D.'s in the Basic Medical Sciences Entering Medical Research Manpower Pool, 1953-1974, from Classes of 1950, 1955, 1960, and 1965	72
26	Estimated Net Increment of Ph.D.'s in the Biosciences Entering Medical Research and Health-Related Research, 1961-1970	74
27	Model for Illustrating Flow of Ph.D.'s in Psychology Entering Medical Research Manpower Pool, 1953-1975, from Classes of 1950, 1955, 1960, 1965	75
28	Distribution by Field of <u>Additional</u> Ph.D.'s Needed to Meet Medical Research Manpower Requirements, 1961-1970	77
29	Comparison Between Estimated Additional Manpower Requirements and Potential Supply of Scientists for Medical Research, 1961-1970	83
30.	Increase in U.S. Population, by Age Groups, 1960-1970	90
31	Population Base for Ph.D. Output, 1930-1960, and Projection to 1970	90
32	Retention Rates of Fifth Graders to College Entrance	93
33	High School Graduates	93
34	College Enrollment, 1956-61	94
35	Comparative Average Annual Percentage Increases in Graduate Enrollment in Selected Science Fields at 74 of 80 Leading Schools, 1953-54 to 1959-60 and 1959-60 to 1960-61	96

List of Tables

<u>Table No.</u>	<u>Title</u>	<u>Page No.</u>
36	Intermediate-Level Graduate Enrollment in Selected Science Fields at 80 Leading Schools, 1960-1961	97
37	Ratio of Output of M.D.'s to Science Ph.D.'s, 1920-1960, and Projection to 1970	100
38	Output and Projections of U.S. Medical School Graduates by Five-Year Periods	103
39	Ph.D.'s Awarded in the Sciences, 1946-1960, and Estimated Output, 1961-1970	109
40	Output of Ph.D.'s in Biosciences and Psychology, 1951-1960, and Projection, 1961-1970	110

LIST OF CHARTS

<u>Chart No.</u>	<u>Title</u>	<u>Page</u>
1	National Expenditures for Medical Research, 1947-1959 and Alternative Projections, 1960-1970	6
2	Flow of Medical Research Manpower by Type of Training, by Field of Specialization, and Type of Employer	12
3	Distribution of NIH First-time Grantees by Degree	19
4	Manpower for Medical and Health-Related Research by Degree, 1960-1970	40
5	Percent Increase in Type of Activity of Physicians, 1949-1959	52
6	Number of Medical Students and Organized Research Expenditures per Full-time Faculty Member, 1951 and 1961	60
7	Enrollment and Dollars of Organized Research per Thousand Faculty in Institutions of Higher Education	81
8	Percent Change in Population Age Groups 1960-1970	89
9	Population Base for Ph.D. Output, 1930-1970	91
10	Ratio of Output of M.D.'s to Science Ph.D.'s, 1920-1960, Projected to 1970	99
11	Enrollment in Institutions of Higher Education	101
12	Number of Science Doctorates Granted During Year	106

SUMMARY

As a general guide for assessing the future magnitude of the Nation's medical research effort, an estimate of \$3 billion for total national expenditures for medical research in 1970 has been widely accepted. An effort to look ahead for a decade is an undertaking obviously fraught with uncertainty. Many as yet unforeseen factors will influence the growth of research expenditures during the Sixties. Thus, it should be emphasized that the \$3 billion projection is not set forth as a goal or target of this Administration. With these qualifications clearly identified, the National Institutes of Health has utilized the \$3 billion projection--about three times the current effort--as a reasonable and feasible basis for estimating research manpower needs. Attainment of a national program of this order of magnitude will involve (1) a greatly accelerated expansion of facilities and equipment for health research and (2) a marked increase in the output of trained investigators--physicians, dentists, osteopaths and veterinarians (included under the term M.D. hereafter for the sake of brevity) and Ph.D.'s in the sciences--and supporting personnel. Specifically, the number of competent personnel must double over the coming decade to staff a program three times the size of the current effort. This calls for an increase in medical research manpower from the current level of about 40,000 to about 80,000 in 1970. The body of this report shows that this required increase in manpower will not be forthcoming unless private and governmental activities aimed at increasing the basic national pool of health personnel are expanded rapidly. In addition to increasing the size of the total pool, efforts to expand the numbers of persons with specific skills will be necessary. These are the essential findings of this report.

The demand for and supply of manpower in 1965 and 1970 cannot be forecast precisely because of the inherent uncertainty of the future. For example, the Nation may be supporting a medical research effort requiring substantially more or substantially less than \$3 billion per year in 1970. For the purpose of this report, the precise level is not controlling, because the training and educational effort required will be urgent whatever reasonable assumption is made as to the future level of research expenditures. If it develops that a \$3 billion effort in 1970 is not feasible, this will be primarily a reflection of a national deficiency in educational and training efforts. This summary stresses the importance of the general implications of the forecasts presented in the body of this report, and the significance of general orders of magnitude, rather than the techniques of forecasting and the precise models emphasized in the body of the report.

In the full text of this report, a single set of estimates is presented for the sake of simplicity, although reasonable alternative assumptions are presented. Relatively small changes in basic assumptions, such as the rate of increase in expenditures per professional worker, tend to produce relatively large changes in projected manpower requirements. However, the requirements produced by any set of reasonable assumptions lead to the same major conclusions.

Trends in Manpower Engaged in Medical Research

The number of professional workers engaged full or part-time in medical research has risen from over 19,000 in 1954 to nearly 40,000 in 1960--more than a 100 percent increase. The dominant characteristics of this growth can be summarized briefly:

- (1) The largest increase has taken place in universities and research institutes;
- (2) The number engaged full-time in medical research has been rising, and those working part-time are devoting a larger share of their energies to research;
- (3) Research opportunities combined with teaching and/or service responsibilities have become increasingly attractive to M.D.'s;
- (4) Participation of Ph.D.-trained manpower has been rising rapidly, accompanied by the growing involvement of the physical and social and behavioral sciences in medical research;
- (5) The underlying supportive force in this development has been the substantial enlargement of national programs for private and public support of research, research training, and construction of research facilities.

Finally, in analyzing the sources of manpower for medical research over the past few years, it must be specifically noted that at the end of World War II there existed a large pool of trained manpower, cumulated through the depression and the war, available for independent investigation. Without this substantial pool of talent as a base, it would have been impossible to man the current national medical research effort. No such pool is available for the future.

In the absence of this pre-trained talent, the future expansion of medical research will be staffed only as a result of a steadily expanding national effort, combining private and public resources, to train manpower specifically for medical research.

Expenditures per Professional Research Worker

Future manpower requirements for medical research in 1970 have been estimated by dividing estimated expenditures per professional worker into total research expenditures. This process has its limitations but it represents at present the best available method. Expenditures per year per professional worker in medical research increased from about \$12,000 in 1954 to about \$18,000 in 1960. This is a compound rate of increase of 5.3 percent per annum if account is taken of price increases between 1954 and 1960.

Expenditures per professional worker will continue to rise during the Sixties, reflecting (1) large-scale clinical research programs which involve high costs per investigator, (2) more complex and precise instrumentation, (3) conduct of large-scale, long-term population studies, and (4) greater use of higher-paid and more highly skilled professional-level technicians. These increased costs will come about even if prices remain constant for the next decade. It is assumed that such forces will result in an 8 percent per annum increase in expenditures per professional worker (expressed in 1960 constant dollars) reaching about \$40,000 in 1970. This is a rate of increase about 50 percent higher than the 5.3 percent rate of increase that has prevailed over the past few years.

Dividing estimated national expenditures of \$3 billion for medical research in 1970 by this increased level of \$40,000 in expenditures per worker, it is estimated that more than 75,000 professional workers in medical research will be needed in 1970. This calls for adding 45,000 professional workers over the decade, including an estimate of about 8,000 needed for replacement due to death, retirement, and shifts to other activities. As is true of other figures in these forecasts, the attrition may be more or less than 8,000. But the net import of

the figures, with any reasonable assumptions as to such things as expenditure per worker and attrition is that the number to be added by 1970 exceeds the total number now at work.

Meeting Manpower Requirements for the Future

What problems will be encountered in adding 45,000 highly qualified professionals for medical research--roughly doubling the manpower available--by 1970? Until the late Sixties, the supply of manpower for medical research will depend almost exclusively upon those who have already received the M.D. or Ph.D. degree, and who are now getting postdoctoral research training or experience. As indicated in the body of this report, it appears probable that about one-half of the additional Ph.D.-trained manpower and roughly two-thirds of the M.D.'s must come from the group already past the basic Ph.D. and M.D. training respectively.

This conclusion is based upon analyses, presented in the body of the report, which show the approximate number of M.D.'s and Ph.D.'s flowing into the pool of fully trained research manpower in given years after receiving their degrees. The Nation is now reaping the benefit of research training programs initiated more than a decade ago.

The remaining doctoral-trained researchers will have to come from those who have not yet received their advanced degrees. Here two factors are important--the total output of M.D.'s and Ph.D.'s in science, and the proportion of this total output engaging in medical research. So far as total output is concerned, it appears that about 75,000

new M.D.'s may be produced between 1960 and 1970. This estimate rests upon maintenance of the productivity of existing schools, full activation of schools already established, and completion of schools now firmly planned. It is also estimated that between 90,000 and 95,000 new Ph.D.'s may be produced between 1960 and 1970, a figure consistent with forecasts of the National Science Foundation. Both of these forecasts rest upon the assumption that deliberate efforts to expand output will be made. The more successful the efforts, the larger the output. The figures further emphasize the fact that enlargement of the pool of M.D.'s and Ph.D.'s in science is fundamental to an expanded medical research effort.

From the total pool available, those who can and will engage in medical research is somewhat problematical. In particular, the mounting demand for more scientists in other activities affecting the national interest will influence the realization of these estimates. In any event, however, it is clear that the required numbers will not be available for research unless:

- (1) Research combined with teaching and/or service becomes an increasingly attractive and productive career pattern for M.D.'s, recognizing that most M.D.'s in research in medical schools and teaching hospitals will contribute to teaching and service, and
- (2) A steadily increasing proportion of Ph.D.'s in the biological and physical sciences, mathematics, engineering, psychology and the other social and behavioral sciences engage in medical research.

These assumptions are in turn dependent upon the continuing stimulus of effectively designed and operated training programs.

Turning to the period after 1970, the resource base for meeting medical research manpower requirements will broaden substantially through (1) a sharp expansion in the population age groups from which new M.D.'s and Ph.D.'s must be drawn, (2) steeply rising enrollment at all levels of higher education. This base, as noted above, will expand most rapidly during the late Sixties and thereafter. But the long-range population trends, fundamentally the consequence of the World War II baby boom, which will create a wave of college students and later advanced degree candidates will affect the supply of new entrants into medical research primarily after 1970. For the years before 1970, the Nation will depend particularly heavily upon deliberate training efforts in the absence of a population age distribution favorable for the production of advanced degree holders.

Implications for National Action

During the past ten years, private and public research and training programs have attracted increasing numbers of doctoral level investigators from all fields of science into medical research. These programs have (1) enlarged opportunities for research, (2) expanded and equipped sorely-needed research facilities, and (3) provided support for research training and for the graduate education process through mechanisms that have aided both students and institutions. All of the existing mechanisms must be retained and expanded, with suitable modifications, if the needed manpower is to be produced.

Additional measures directed primarily at expanding the total pool of manpower and initiated as soon as possible are called for to expand the manpower supply for the long run:

- 1) Expand college matriculation, especially among more talented, less privileged youth.
- 2) Enlarge graduate enrollment in all fields, but especially in fields most directly relevant to medical research.
- 3) Increase the number of medical students as rapidly as possible to assure an adequate future supply of physicians to meet all the health needs of the Nation.
- 4) Accelerate the output of Ph.D.'s.
- 5) Orient the Nation's youth toward the exciting challenges and rewarding career opportunities in biology and medicine.

Thus, in the final analysis, meeting the Nation's future requirements for medical research manpower will depend upon national policy and action at both the Federal and nonFederal levels designed to

- (1) provide more general support for the graduate education process,
- (2) reduce the attrition and accelerate the flow of graduate students toward the Ph.D. degree, (3) expand research and teaching facilities to accommodate steadily growing research activities and rapidly rising enrollment, (4) enlarge the Nation's capabilities for specialized and intensified research training at the postdoctoral level, (5) develop an adequate supply of highly skilled professional-level technicians,

as well as technicians at lower levels, demanded to assist in increasingly complex, highly instrumented research activities, and (6) assure stable and rewarding career opportunities under conditions most suited to productive scientific inquiry.

The essence, therefore, of the findings of this study is that staffing a research program in 1970 that will be about three times as large in dollar terms as the program in 1961 will produce manpower demands that will not be satisfied without a vigorous and diversified set of programs for the training of manpower, including but going far beyond programs administered by the Public Health Service. And, the major contingency which must be borne in mind is that the satisfying of these specific demands for medical research manpower without a substantial enlargement of the basic professional manpower pool will adversely affect the attainment of other national objectives, such as provision of more physicians for medical care and the staffing of other urgent scientific efforts.

On the other hand, the situation facing the Nation is such that the possibility of educating and training too many people for medical and related research need not be seriously considered. The Nation will use all who can be produced, provided they are soundly educated. The central problem is not to undertake a fine adjustment of supply and demand, but to expand the pool as rapidly as possible, with stress upon the quality of training.

MANPOWER RESOURCES AND REQUIREMENTS FOR
MEDICAL AND HEALTH-RELATED RESEARCH, 1965-1970

I. INTRODUCTION

In its Report on the 1962 Appropriation for the Department of Health, Education and Welfare, the House Committee on Appropriations observed that:

"No convincing evidence was submitted which would indicate that the present levels of the research training programs are sufficient to assure the country of a steady and adequate supply of highly qualified research manpower in each of the important--and especially in the rapidly growing--scientific and inter-disciplinary areas relevant to medical research."

The Committee therefore requested that the National Institutes of Health prepare a balance sheet on estimated research manpower requirements five and ten years hence and a projection of expected output. In response to the Committee's request, the National Institutes of Health has prepared this Report which attempts to (1) assess the nation's manpower requirements for medical and health-related research in the decade ahead; (2) compare requirements with anticipated resources (available supply versus probable demand); (3) analyze whether anticipated output will be adequate to meet projected demand; and (4) set forth the implications of this analysis for NIH activities that provide support for research, training, and expansion of research facilities.

In recent years, the National Institutes of Health has undertaken a comprehensive and systematic program of studies and analyses of all aspects of medical and health-related research manpower resources and requirements. This involves the development and correlation of existing data and studies

bearing upon utilization, requirements, supply, and production of professional and scientific manpower in medical and health-related research, identification of critical data needed for manpower planning, and projection of manpower needs in relation to expected levels of medical research expenditures and educational activity. Consequently, in the preparation of this report, every effort has been made to draw upon up-to-the-minute information on the employment and training of research manpower in all fields related to health.

Because medical and health-related research comprises a broad area of scientific inquiry aimed ultimately at the improvement of human health and the conquest of disease, it draws upon all fields of science - biological, medical, physical, engineering, psychological, and social - and many disciplines within each field.

The range of occupational choice open to scientific and professional manpower in these health fields encompasses three major areas of activity: (1) Research (2) Teaching and (3) Service and related activities. Any estimate of future demand is inevitably complicated by the fact that a substantial proportion of all scientists in these fields now engage, more often than not, in more than one of the three above-mentioned activities simultaneously. Most frequently, a scientist combines research and teaching in his career. Quite often, research and service or teaching and service are combined as the career pattern. Thus, the total demand for medical research manpower for the future must be viewed in the perspective of such multiple activities rather than the assumption that individuals will be engaged solely in one of these major forms of career activity. Nevertheless, research needs and opportunities constitute the single, most powerful influence upon the demand for scientific manpower.

II. THE FUTURE GROWTH OF MEDICAL RESEARCH

The primary factor determining medical research manpower needs is the growth of medical research itself. Research expenditures constitute the best single quantitative measure of such growth. The Nation's medical research expenditures have risen six-fold between 1950 and 1961, from \$148 million to \$890 million in 1961. ^{1/}

Table 1

The Nation's Expenditures for Medical and
Health-Related Research, 1950-1961

<u>Year</u>	<u>Amount</u> (in millions)
1950	\$148
1955	240
1960	715
1961	890 ^{1/}
Ratio 1961/1950	6.0

This steady and substantial expansion in the Nation's expenditures for medical research has created new horizons of research opportunity through:

(1) Rising Federal support, especially through the programs of the National Institutes of Health.

(2) The construction of at least \$300 million of health research facilities has been catalyzed by \$150 million of Health Research Facilities funds.

^{1/} The Nation's expenditures for medical and health-related research actually exceeded \$1 billion in 1961. The increase reflects better coverage of Federal expenditures and expenditures in the medical supply and medical electronics sectors of industry. As soon as possible, the basic series on the Nation's expenditures for medical and health-related research from 1947-1961 will be adjusted to reflect improvements in coverage since 1957. However, the \$890 million estimate for 1961 is used throughout this analysis in order to permit comparison with prior years.

(3) Support of research in literally hundreds of separate nuclei of research competence.

(4) Creation of clinical research centers.

(5) Establishment of long-range research programs in areas such as aging, perinatal mortality, human population laboratories, viral origins of cancer, and child health.

(6) Spread of medical research into social problem areas such as juvenile delinquency, alcoholism, mental retardation and school health.

(7) Acceleration of discovery and innovation in the pharmaceutical, medical supply, and medical electronics industries.

(8) Stimulation of additional manpower needs in the physical and behavioral sciences to keep pace with the ever-enlarging scope of research opportunities.

In recent years, two distinguished groups of private citizens faced up to the problem of projecting probable levels of the Nation's medical research expenditures in the future, taking into account these recent trends and emergent opportunities. ^{1/} Each relied upon the same method and both regarded these projections as a useful framework for long-range planning but cautioned against treating them as rigid targets for budgetary purposes.

The Bayne-Jones Report, published in 1958, estimated that the Nation's expenditures for medical research would reach \$1 billion by 1970. The Consultants cautioned that their projections were conservative. Actual expenditures for medical research in 1957-60 have far outstripped the trend line aimed at the \$1 billion level for 1970. The estimate of \$1 billion for 1970 developed in the Bayne-Jones Report will, in fact, be reached by 1962.

^{1/} The Advancement of Medical Research and Education, Final Report of the Secretary's Consultants on Medical Research and Education, Department of Health, Education and Welfare, Office of the Secretary, 1958; Federal Support of Medical Research, Report of the Committee of Consultants on Medical Research to the Subcommittee on Departments of Labor and Health, Education and Welfare of the Committee on Appropriations, United States Senate, 86th Congress, May 1960.

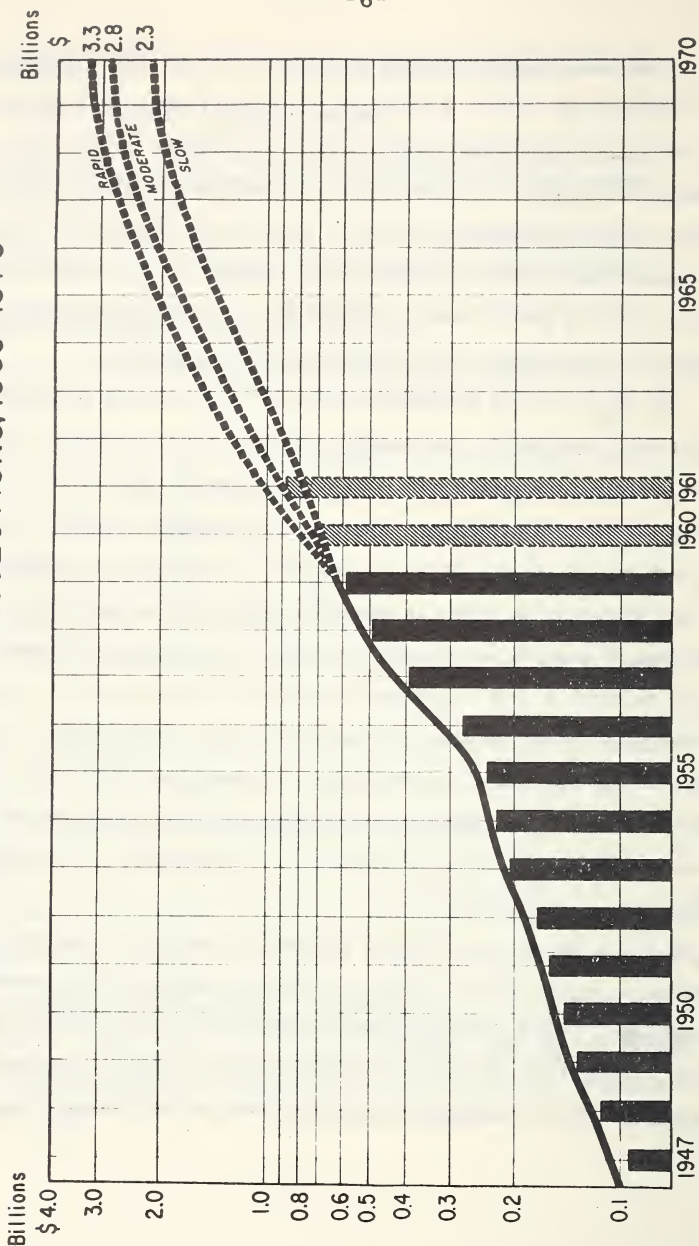
The Jones Committee (taking note of the 1957-60 developments) expressed its belief that by 1970 the total support of medical research in the United States will probably require annual expenditures of \$3 billion. In arriving at this estimate, the Committee utilized projections indicating a possible range of medical research expenditures in 1970 of \$2.8 billion to \$3.3 billion (Chart 1). Such projections are useful in establishing probable ranges of future expenditures in terms of general orders of magnitude; they are essential to any appraisal of the probable future demand for research manpower.

An effort to look ahead for a decade is an undertaking obviously fraught with uncertainty. The numerous assumptions that are made in the pages which follow are reasonable ones. Yet they are not the only equally plausible assumptions which might be made. The range of reasonable estimates is quite wide with respect to many of the critical factors involved. (See Appendix A for full discussion of trends in research expenditures and methodology used in developing alternative projections for 1970). Nevertheless, the fundamental fact to be borne in mind in reading the projections which follow is that any reasonable set of assumptions produces heavy and continuing demands for trained manpower. Any reasonable, alternative set of assumptions which might be adopted in preference to those appearing in this manuscript would not alter the essential policy conclusion that intensive efforts will be required to staff the Nation's medical research effort in 1970.

Thus, the \$3-billion projection for 1970 for medical and health-related research is not set forth as a goal or target but rather as a reasonable approximation. The \$3 billion projection which calls for a trebling of the Nation's expenditures for medical and health-related research in 1970 has been utilized by NIH as a reasonable, sound basis for estimating research manpower needs.

Chart 1

NATIONAL EXPENDITURES FOR MEDICAL RESEARCH, 1947-1959 AND ALTERNATIVE PROJECTIONS, 1960-1970



SOURCE: National Institutes of Health

RAS-OPP-NIH-12/61

Realization of a \$3 billion effort will involve a greatly accelerated expansion of facilities, equipment, and institutions and will demand substantially greater numbers of scientists. The crucial question is:

Given the projected level of \$3 billion, what does this mean in terms of the supply and characteristics of medical research manpower needed by 1965 and 1970?

To answer this question, this report will:

1. Consider the trends in the distribution of scientists engaged in medical and health-related research, 1954-1960.
2. Examine the current distribution by sector, field, level of training, proportion of time in research, and the relevance of these characteristics for 1970 projections.
3. Assess the trends in expenditures per professional worker since 1954, making due allowance for inflation;
4. Use estimated expenditures per professional worker to forecast future requirements by sector, field, and level of training;
5. Obtain net additional requirements for 1970 by subtracting estimated losses through:
 - a. Death
 - b. Retirement
 - c. Movement out of medical research into other activities.
6. Estimate the flow of professional workers into the medical research manpower pool, 1965-1970, from:
 - a. U.S. output of scientists for medical research at all relevant degree levels
 - b. Immigration.
 - c. Entrance of qualified investigators into medical research from other research areas or kinds of activity.
7. Evaluate the outlook for output of M.D.'s and Ph.D.'s, 1960-1970.
8. Discuss implications for national policy involved in meeting medical research manpower needs.

The 1970 time perspective is short run; not long range. The additional supply through 1965 are either recent recipients of the Ph.D. or M.D. or those now receiving graduate and professional training. The additional supply, 1966-1970, must, in large measure, be drawn from those now in postdoctoral training and those now enrolled in graduate schools and medical schools. Those who entered college this year, 1961-62, will not graduate until 1965 and hence will not complete their graduate and postdoctoral training before 1970 at the earliest. Consequently, this analysis concentrates primarily upon (1) those now engaged in medical research and (2) those who can be expected to enter the research manpower pool by 1970.

In the analysis to follow, this report is concerned with more than mere numbers; it is concerned with (1) the supply of well-qualified scientists capable of performing as independent investigators and (2) the quality of training required to realize the Nation's medical research potential. The scope of the report does not include any quantitative estimate of the demand for technicians generated by a \$3 billion medical research effort. It is clear, however, that the expansion of scientific manpower will have to be matched by a complementary enlargement in the supply of highly skilled, professional-level technicians and sub-professional supporting staff.

III. SCIENTIFIC MANPOWER ENGAGED IN MEDICAL AND HEALTH-RELATED RESEARCH, 1954-1960.

As a first step in estimating manpower needs for the future growth of medical research, it is helpful to analyze significant trends and to examine the current distribution of manpower now engaged in medical research. This analysis becomes most meaningful for the consideration of future requirements when the gross statistical aggregates are broken down into their critical components. For medical research manpower, the critical components are: (1) type of employer, (2) field of specialization, and (3) level of training. The interrelationships of these components are depicted on Chart 2.

1. Type of Employer. While it is true that some scientists are self-employed, most medical research scientists work in three different research environments or sectors of the research economy: Government, industry, academic institutions, and nonacademic research organizations. The term "universities and research institutes," which is used throughout this report, refers to and encompasses universities, medical schools, hospitals, research institutes (both nonprofit and other), community agencies, and foreign institutions.

Scientists employed in each of these three research environments differ significantly in terms of fields and type of training required and in terms of complementary responsibilities other than research. Consequently, it is important to analyze the present and probable future employment patterns by sector.

2. Level of Training. Medical research manpower is frequently equated with M.D. preparation. The validity of this assumption can be examined in the light of knowledge about (1) the distribution of scientific and professional manpower now engaged in medical research and (2) the types of training required for the scientific disciplines and professional specialties involved.

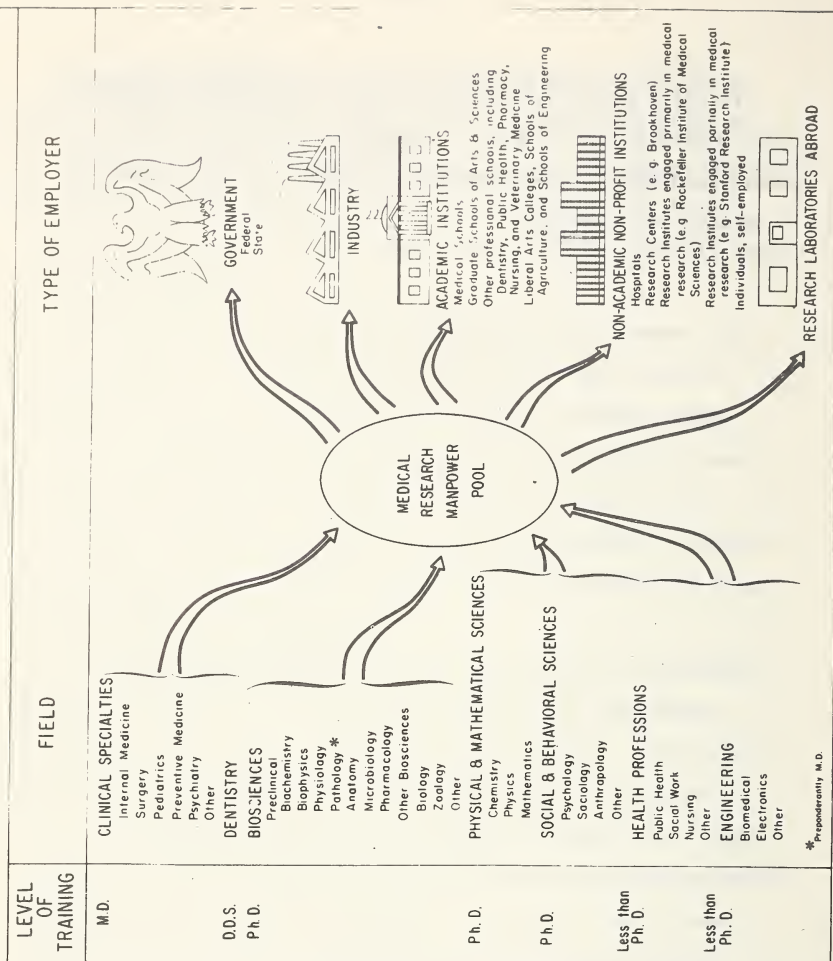
It is often presumed that the growing complexity of science, the accelerated pace of new knowledge, the increasingly higher levels of intellectual and experimental inquiry, all combine to demand rigorous training through the doctoral level as a prerequisite to entrance into the professional research labor force. Again, the validity of the presumption can be evaluated objectively through an analysis of the type of training possessed by those now engaged in medical research and recent trends influencing this distribution.

3. Field of Specialization. Medical research absorbs the creative energies of men from all fields of science and from many disciplines within each field. This is by no means a new development. Chemists and biologists have long contributed to the progress of medical research. Likewise, psychologists, psychiatrists, and social scientists have sought to apply their skills as medical research has extended beyond the physical and biological manifestations of disease to the myriad facets of human behavior. More recently, the opportunity to apply concepts from the mathematical and physical science to the exciting and fruitful study of biological phenomena has attracted increasing numbers of physicists, mathematicians, and engineers.

The rapid growth of knowledge in all of these fields has demanded ever-increasing specialization. Consequently, an adequate view of present employment and future requirements must focus upon the fields of specialization involved.

Chart 2

FLOW OF MEDICAL RESEARCH MANPOWER BY TYPE OF TRAINING, BY FIELD OF SPECIALIZATION, AND TYPE OF EMPLOYER



* Preprofessional M.D.

SOURCE: Resources Analysis Section, OPP-NIH

A. Trends in Employment of Scientific and Professional Manpower in Medical and Health-Related Research, 1954-1960

Between 1954 and 1960, the Nation's medical research expenditures more-than trebled from \$225 million to \$715 million. The estimated number of professional workers in medical research also increased but at a slower rate. The total number in medical research is estimated to have doubled from 19,200 to 39,700 in this period -- a net increase averaging 3,500 per year (Table 2).^{1/} Thus, the amount of the increase in this six-year span exceeded the total number in medical research in this sector in 1954.^{2/}

What are the key qualitative characteristics of this increase in the number of scientists engaged in medical research?

1. The major expansion is occurring in universities and research institutes. Scientists in universities and research institutes represented 12,600 of the additional 20,500 scientists entering medical research, 1954-1960. Table 3 shows that the participation of scientists in universities and research institutes has increased more rapidly in recent years - roughly 69 percent of the 1958-1960 increase as compared with 62 percent over the total period, 1954-1960. This more rapid growth in recent years reflects, at least in part, the substantial expansion of NIH research grant programs.

^{1/} For comprehensive discussion of sources and methodology, see Appendix Tables 1-4.

^{2/} It should be noted that the data for 1958 and 1960 were derived in a different manner from 1954 figures. The 1954 data were obtained, in large part, from the first national surveys undertaken by the National Science Foundation. The 1958 and 1960 data are derived primarily from surveys conducted or stimulated by the Resources Analysis Section, Office of Program Planning, NIH, and from related analyses. As a consequence of these extensive survey and analytical activities, we are in better position to assess the 1958 and 1960 data with confidence. However, while the 1958 and 1960 data reflect somewhat more comprehensive coverage than the figures for 1954, it is believed that comparability between 1954 and subsequent years is well within the ± 5 percent range. The analysis of trends, therefore, should be interpreted with this minor qualification in mind.

2. The proportion of time devoted to medical research is increasing.
Numbers alone fail to convey adequately the character of this rising participation in medical research. Comparison between 1954 and 1960 shows that (1) an increasing number of scientists now engage full-time in research and (2) those engaged part-time in research now devote a greater share of their total intellectual effort to this activity (Table 4). The number of part-time researchers has increased from nearly 8,000 (7,940) to approximately 20,000 (20,300). Not only has the number of part-time researchers increased, but these scientists are devoting a greater proportion of their time to research. Between 1954 and 1960, the full-time equivalents of part-time researchers mounted 188 percent, as compared with 155 percent for part-time researchers. And, as indicated in Table 5, these full-time equivalents of scientists engaged part-time in research have been increasing steadily as a proportion of all full-time equivalents -- from nearly 20 percent in 1954 to almost 30 percent in 1960.

Table 2

Scientific and Professional Manpower Engaged in Medical and Health-Related Research by Sector, 1954, 1958 and 1960

Sector	1954	1958	1960	Increase of 1960 over 1954
Total	<u>19,200</u>	<u>34,600</u>	<u>39,700</u>	<u>20,500</u>
Government	3,700	6,900	7,800	4,100
Industry	3,400	6,500	7,200	3,800
Universities and research institutes	12,100	21,200	24,700	12,600

SOURCE: National Institutes of Health.

Table 3

Percent Distribution of Increase in Scientific and Professional Manpower Engaged in Medical and Health-Related Research by Sector, 1954-1960 and 1958-1960

Sector	1954-1960 Increase	1958-1960 Increase
	N - 20,500	N - 5,100
Total	<u>100.0</u>	<u>100.0</u>
Government	20.0	17.7
Industry	18.5	13.7
Universities and research institutes	61.5	68.6

SOURCE: National Institutes of Health.

Table 4

Number and Full-time Equivalent of Scientific and Professional Manpower Engaged in Medical and Health-Related Research, 1954, 1958 and 1960

Time factor	1954	1958	1960	Increase 1954-1960	
				Number	Percent
Total number	19,200	34,600	39,700	20,500	106.8
Full-time equivalent	(14,000)	(23,100)	(27,285)	(13,285)	(94.9)
Full-time	11,260	17,245	19,400	8,140	72.3
Full-time equivalent of part-time	(2,740)	(5,855)	(7,885)	(5,145)	(187.8)
Part-time	7,940	17,355	20,300	12,360	155.7

SOURCE: National Institutes of Health.

Table 5

Percent Distribution of Full-time Equivalent of Scientific and Professional Manpower Engaged in Medical and Health-Related Research, 1954, 1958 and 1960

Time factor	1954	1958	1960
	N - 14,000	N - 23,100	N - 27,285
Full-time equivalent	100.0	100.0	100.0
Full-time	80.4	74.7	71.1
Full-time equivalent of part-time	19.6	25.3	28.9

SOURCE: National Institutes of Health.

3. Participation of Ph.D.'s in medical research is rising. This pattern of increasing part-time research involvement reflects, in large measure, the rising participation of doctoral-trained manpower, especially Ph.D.'s, in medical research. Manpower data by level of training are available for 1958 and 1960 but were not obtained in 1954. Between 1958 and 1960, the proportion of doctoral-trained researchers rose from 71 percent to 74 percent of all professional workers ^{1/}engaged in medical and health-related research (table 6). The full significance of this apparently modest increase is reflected in the distribution of the 5,100 additional professional workers who entered medical research, 1958-1960. Table 7 shows that (1) doctoral-level researchers represented more than nine-tenths (92.4 percent) of the total increment and (2) Ph.D.'s comprised 70 percent of the doctoral group.

This shift toward rising involvement of Ph.D.'s is corroborated by an analysis of NIH first-time grantees. The comparison between 1950 and 1960 reveals the longer-term character of this change (chart 3).

^{1/} The term "professional worker" means M.D.'s, Ph.D.'s, and others with less than doctoral training who functioned as principal investigators and collaborators. In general, it does not include persons with such training who performed as research assistants. It also excludes technicians and all other supporting personnel. It should be noted, however, that Federal and State personnel classification systems and industrial employment practices are keyed more closely to position descriptions than to the more rigorous standards applied in universities and research institutes.

Table 6

Scientific and Professional Manpower Engaged in Medical and Health-Related Research by Level of Training, 1958 and 1960

Level of training	1958	1960	Percentage distribution	
			1958	1960
Total	<u>34,600</u>	<u>39,700</u>	<u>100.0</u>	<u>100.0</u>
Doctoral	<u>24,690</u>	<u>29,400</u>	<u>71.4</u>	<u>74.1</u>
M.D., D.D.S., D.V.M.	<u>9,990</u>	<u>11,400</u>	<u>28.9</u>	<u>28.7</u>
Ph.D., Sc.D.	<u>14,700</u>	<u>18,000</u>	<u>42.5</u>	<u>45.4</u>
Less than doctoral (M.S., M.P.H., M.A., B.S., A.B.)	<u>9,910</u>	<u>10,300</u>	<u>28.6</u>	<u>25.9</u>

SOURCE: National Institutes of Health.

Table 7

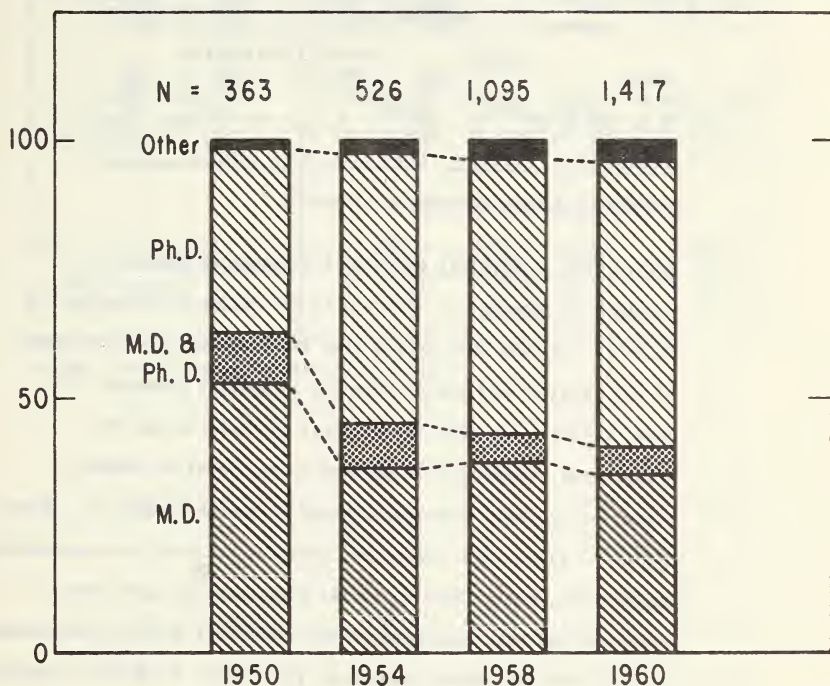
Percentage Distribution of Increase in Scientific and Professional Manpower Engaged in Medical and Health-Related Research by Level of Training, 1958-1960

Level of training	Increase 1958-1960	
	N - 5100	
Total	<u>100.0</u>	
Doctoral	<u>92.4</u>	(100.0)
M.D., D.D.S., D.V.M.	<u>27.7</u>	(29.9)
Ph.D., Sc.D.	<u>64.7</u>	(70.1)
Less than doctoral (M.S., M.P.H., M.A., B.S., A.B.)	<u>7.6</u>	

SOURCE: National Institutes of Health.

DISTRIBUTION OF NIH FIRST-TIME GRANTEES BY DEGREE

Percent



SOURCE: National Institutes of Health

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Table 8

Distribution of NIH First-Time Grantees by Level of Training

Level of training	Years			
	1950	1954	1958	1960
Number	<u>363</u>	<u>526</u>	<u>1095</u>	<u>1417</u>
	Percent distribution			
Total	<u>100</u>	<u>100</u>	<u>100</u>	<u>100</u>
M.D.	<u>52</u>	<u>36</u>	<u>37</u>	<u>35</u>
M.D. and Ph.D.	<u>10</u>	<u>9</u>	<u>6</u>	<u>6</u>
Ph.D.	<u>37</u>	<u>53</u>	<u>54</u>	<u>55</u>
Other	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>

Source: National Institutes of Health.

4. Involvement of physical and social sciences in medical research is growing. In addition to the rising participation of Ph.D.'s, the 1954-1960 period also witnessed growing involvement of the physical and social sciences in medical research. In 1954, fields other than the clinical specialties and the biosciences represented 22 percent of the total in medical research; by 1960, they approximated 29 percent (table 9). These fields -- psychology, chemistry, physics, sociology and anthropology, engineering, public health, social work, nursing, and others -- accounted for over one-third of the additional 20,500 professional workers entering medical research, 1954-1960. While this broadening of the scientific base for medical research represents a significant trend, it should be emphasized that the biosciences comprise by far the largest group, both numerically (more than 17,000 in 1960) and proportionately (close to 45 percent of the total).

Table 9

Scientific and Professional Personnel Engaged in Medical and Health-Related Research by Field, 1954, 1958 and 1960

Field	1954	1958	1960	Increase 1954-1960
	<u>Number</u>			
All science fields	19,200	34,600	39,700	20,500
Clinical specialties	6,250	9,570	10,915	4,665
Biosciences	8,700	14,855	17,160	8,460
All other sciences	4,250	10,175	11,625	7,375
	<u>Percentage distribution</u>			
All science fields	100.0	100.0	100.0	100.0
Clinical specialties	32.6	27.6	27.5	22.7
Biosciences	45.3	43.0	43.2	41.3
All other sciences	22.1	29.4	29.3	36.0

SOURCE: National Institutes of Health.

Summary

In brief, the trends, 1954-1960, show:

1. More than a 100 percent increase in the number of professional workers engaged in medical and health-related research.
2. An increase of more than 12,500 scientists engaged in medical research in universities and research institutes. Between 1958 and 1960, this sector accounted for more than two-thirds (68.6 percent) of the additional manpower in medical research.
3. The number engaged full-time in medical research in universities and research institutes is rising. More important, the number working part-time in research is increasing more rapidly, and because they are devoting a larger share of their energies to research, the number of full-time equivalents per part-time researcher is mounting at an even steeper rate.
4. Rising participation of Ph.D.'s. This group constituted 70 percent of the additional doctoral-trained manpower entering medical research, 1958-1960.
5. The 1954-1960 period also witnessed a broadening of the scientific base for medical research with growing involvement of the physical and social and behavioral sciences.

B. Professional Workers Engaged in Medical and Health-Related Research in 1960.

The 1960 distribution provides the base to which additional manpower must be added to meet requirements for 1970. Consequently, the data for 1960 are presented in greater detail because they bear so directly upon the composition of manpower needs for the future.

1. More than three-fifths of scientists in medical research are now located in universities and research institutes. It is estimated that 24,700 scientists, or roughly 62 percent of the 40,000 (39,700) medical research workers in 1960 were working in universities, medical schools, graduate schools, hospitals, research institutes, and other academic and nonacademic institutions participating in the Nation's medical research effort (table 10). The balance of 15,000 professional workers were divided about evenly between industry and Government.
2. Over three-fourths of the doctoral-trained researchers work in universities and research institutes. In 1960, nearly four-fifths (77.9 percent) of the M.D.'s and about three-fourths (75.2 percent) of the Ph.D.'s in medical research worked in a university, teaching hospital, or research institute environment (table 10). Industry and Government employed about one-fourth of those with doctoral training as contrasted with nearly four-fifths (77.7 percent) of the medical research workers with less than doctoral training. These distributions between M.D., Ph.D., and less than doctoral training can be interpreted more meaningfully in terms of manpower requirements for the future when field of science is matched with sector.

Table 10

Number and Percentage Distribution of Scientific and Professional Manpower Engaged in Medical and Health-Related Research, 1960

Sector	Level of training			
	Total	M.D. & D.D.S.	Ph.D.	Other
A. Percentage distribution by sector				
Number	39,700	11,400	18,000	10,300
Total	100.0	100.0	100.0	100.0
Government	19.7	17.3	12.6	34.5
Industry	18.1	4.8	12.2	43.2
Universities and research institutes	62.2	77.9	75.2	22.3

B. Percentage distribution by level of training					
	Number	Level of training			
		Total	M.D. & D.D.S.	Ph.D.	Other
Total	39,700	100.0	28.7	45.3	26.0
Government	7,800	100.0	25.3	29.2	45.5
Industry	7,200	100.0	7.6	30.6	61.8
Universities and research institutes	24,700	100.0	35.9	54.8	9.3

SOURCE: National Institutes of Health.

3. All fields of science now participate in medical research.

Of the 39,700 professional workers shown in Table 11, over two-fifths of the total were in the biosciences, about one-fourth in the clinical medical specialties, more than one-sixth in the physical, mathematical and engineering sciences, and better than one-tenth spread among the social and behavioral sciences (primarily psychology), the health professions, and all other fields. This broad distribution illustrates the substantial participation in medical research from many diverse fields of science.

With the exception of the biosciences, however, the distribution varied significantly by field from sector to sector. For example, physical scientists comprise nearly half (45.8 percent) of the medical research workers employed by industry as against only 11 percent of the scientists engaged in medical research in universities and research institutes. Most of these physical scientists in industry are chemists, and only a small proportion of them hold doctoral degrees. ^{1/}

By way of contrast, less than one percent of the 3,300 (3,255) social and behavioral scientists in medical research in 1960 were employed by industry, with 60 percent of these scientists working in universities and research institutes and nearly 40 percent in Government. It is quite likely, however, that the future may see a greater diffusion of all fields of science among the three sectors.

¹ Pharmaceutical Manufacturers Association Annual Survey of Industry Personnel in Drug or Medical Research and Development, 1959 and 1960.

Table 11

Number and Percent Distribution of Scientific and Professional Manpower
Engaged in Medical and Health-Related Research by Sector and Field,
1960

Field		Sector			
		All fields	Govern- ment	Industry	Universities and research institutes
A. Percent distribution by field					
	Number	39,700	7,800	7,200	24,700
Total		100.0	100.0	100.0	100.0
Clinical specialties		26.0	23.1	7.0	32.4
Dentistry		1.5	1.4	-	2.0
Biosciences		43.2	38.6	43.8	44.5
Physical science, mathematics, and engineering		17.8	13.4	45.8	11.0
Social and behavioral sciences		8.2	16.5	0.3	7.9
Health professions and all other		3.3	7.0	3.1	2.2
B. Percent distribution by sector					
	Number				
Total	39,700	100.0	19.7	18.1	62.2
Clinical specialties	10,305	100.0	17.4	5.0	77.6
Dentistry	610	100.0	18.0	-	82.0
Biosciences	17,160	100.0	17.5	18.4	64.1
Physical science, mathe- matics and engineering	7,045	100.0	14.9	46.8	38.3
Social and behavioral sciences	3,255	100.0	39.4	0.6	60.0
Health professions and all other	1,325	100.0	41.5	17.0	41.5

SOURCE: National Institutes of Health; Industry sector - Pharmaceutical
Manufacturers Association.

4. Most doctoral-trained scientists combine medical research with teaching, service, and related activities. As indicated previously (p. 23), roughly three-fourths of the doctoral manpower in medical research work in universities and research institutes. These 22,400 doctoral-trained scientists represent almost 11,400 full-time equivalents (table 12). This means about five full-time equivalents for every ten medical researchers with doctoral training. The proportion is somewhat higher for Ph.D.'s and, as might be expected, substantially lower for M.D.'s (every 10 M.D.'s represent 3.4 full-time equivalents). This relatively low proportion of full-time equivalents for medical researchers with doctoral training illustrates that most of these scientists engage in research as a part-time activity in conjunction with teaching and/or service responsibilities in educational institutions, teaching hospitals, and research institutes.

Table 12

Relation Between Estimated Number and Full-Time Equivalents of Scientific and Professional Manpower Engaged in Medical and Health-Related Research in Universities and Research Institutes by Level of Training, 1960

Level of training	Number of professional workers	Full-time equivalents	Number of FTE per 10 professional workers
Total	<u>24,700</u>	<u>13,025</u>	<u>5.3</u>
Doctoral	<u>22,400</u>	<u>11,375</u>	<u>5.1</u>
M.D. and D.D.S.	8,875	2,975	3.4
Ph.D.	13,525	8,400	6.2
Less than doctoral	2,300	1,650	7.2

SOURCE: National Institutes of Health

Summary

To recapitulate, the distribution of the 39,700 professional workers engaged in medical and health-related research in 1960 constitutes the base to which future manpower requirements must be added.

1. Three-fourths of the total held doctoral degrees; one-fourth had formal academic training less than the doctoral level.

2. Three-fifths of the total are engaged in medical research in the universities and research institutes; one-fifth each worked in industry and Government.

3. All fields of science participated, with the biosciences and the clinical medical specialties accounting for roughly 70 percent of the total. The remaining 30 percent were concentrated primarily in the physical and the social and behavioral sciences.

4. Because research goes hand-in-hand with teaching and/or service for the 22,400 M.D.'s and Ph.D.'s in medical schools, universities, teaching hospitals, and similar multipurpose institutions, every 10 professional workers with doctoral training represents only 5 full-time equivalents.

IV. MANPOWER REQUIREMENTS TO MEET THE FUTURE GROWTH OF MEDICAL RESEARCH

The simplest method of estimating manpower requirements for future levels of medical research is to apply the divisor of expenditures per professional worker to the dividend of future medical research expenditures. ^{1/} In utilizing this approach, the following reservations must be recorded:

1. Expenditure per professional worker is less than cost per professional worker, with the exception of the industry sector. Why is this so? Expenditure per professional worker is the quotient obtained by dividing research expenditures by the number of professional workers engaged in that activity. Costs represent the sum total of all charges properly allocable to research activities that are borne by the organizations engaged in research. Expenditures per professional worker tend to understate costs per researcher particularly in universities, medical schools, and teaching and research hospitals. This is true, for example, when the total salary of the part-time investigator engaged in sponsored research is paid by the institution employing him for his total services, and no portion of his salary is charged to the organization providing support for the research activity. Moreover, many academic institutions, in contrast

^{1/} The desirability of using this method to develop estimates of future research manpower requirements is discussed in The Long-Range Demand for Scientific and Technical Personnel: A Methodological Study, National Science Foundation, 61-65, 1961, which states that:

"In developing estimates of future employment of scientists and engineers in R & D, it would be logical to utilize a relationship with levels of R & D activity as measured by expenditures. R & D dollars to personnel ratios for several past years and for most sectors of the economy might be worked out from available data. However, no projections of R & D expenditures which could be used in forecasting personnel requirements have yet been developed." (p. 2). The essential difference between this document and the NSF methodological study is that this document does project medical R & D expenditures at a \$3 billion level for 1970.

to industry, do not receive full indirect costs from those who support their research. Thus, that portion of indirect costs for research absorbed by the institution is also excluded from the Nation's research expenditure accounts. For the Government sector, expenditures also understate "costs". This is necessarily so because research in Federal and State hospitals is conducted on a part-time basis by M.D.'s and Ph.D.'s whose primary functions are related to service and patient care and whose salaries normally are not allocated between these primary functions and the complementary activity of research.

2. The term "professional workers," particularly in the industry and Government sectors, includes a substantial proportion (26 percent in 1960) of persons possessing less than doctoral level preparation. The average expenditure per professional worker increases substantially if the term is restricted to persons having a minimum of doctoral level preparation.

A. Expenditures per Professional Worker in Medical Research, 1954-1960

Expenditure per professional worker in all research and development has been rising steadily since 1954. According to the National Science Foundation, research funds doubled between 1954 and 1958 while the number of scientists and engineers increased only 50 percent. For the Nation's total research and development effort, this approaches an average increase in expenditures per professional research worker of more than one-third (35 percent) in a brief four-year span (table 13). During the same period, expenditures per professional worker in medical research increased by one-fifth (21 percent). Thus, it appears that expenditures per professional worker are rising less rapidly in medical research than in all R & D. This higher expenditure

per professional worker in nonmedical research activity reflects in large measure the more intensive use of instrumentation and costly equipment such as particle accelerators, wind tunnels, rocketry and space research facilities.

Table 13

Comparison of Scientific and Professional Manpower in All Research and Development and in Medical and Health-Related Research, 1954-1958

Type of research activity	1954	1958	Increase	
			Amount	Percent
All research and development expenditures (millions)	\$5,620	\$11,160	\$5,540	99
Research manpower (thousands)	225	331	108	48
Expenditures per professional worker (thousands)	\$25.0	\$33.7	\$8.7	35
Medical and health-related research expenditures (millions)	\$225	\$490	\$265	118
Research manpower (thousands)	19.2	34.6	15.4	80
Expenditures per professional worker (thousands)	\$11.7	\$14.2	\$2.5	21

SOURCE: National Science Foundation and National Institutes of Health.

Despite the fact that expenditures per professional worker in medical research are not increasing as rapidly as in other research areas, such expenditures have nevertheless risen sharply since 1954. This rise in expenditure per professional worker in medical research reflects the influence of two general factors:

1. The economic or inflationary influence of rising prices and wages.
2. The substantive influence of the growing complexity of research requiring (1) more elaborate instrumentation, (2) increased technical support per professional research worker, and, in some instances, (3) activities systematically organized on a larger scale and over longer periods of time.

In addition to these general factors, two special considerations have and will continue to increase expenditures per professional worker engaged in universities, medical schools, and related nonacademic research institutions:

1. A 7 percent per year increase in faculty salaries -- far above the 4 percent increase in average annual earnings of all employees for the economy as a whole.
2. More important, universities and research institutions are increasingly adopting the practice of allocating faculty effort between pedagogic and research grant activities and charging that portion of time spent on research projects to the cost of the project itself. This practice is gaining momentum, especially following the recommendation of the Seaborg Panel of the President's Science Advisory Committee that universities, as a matter of national policy, should "strengthen their faculties for both research and graduate teaching by accepting and using Federal as well as nonFederal support for faculty salaries." 1/

1/ The President's Science Advisory Committee, Scientific Progress, Universities and the Federal Government, 1960, p.23.

B. Projections of Expenditures per Professional Worker, 1961-1970

In the light of 1954-1960 experience, what is the outlook for expenditures per professional worker over the next decade?

Excluding the inflationary influence, which, however, may have further substantial effects, it is highly probable that the substantive costs of research will continue to mount. Between 1954 and 1960, expenditures per professional worker in medical research increased at a compound rate of 7.5 percent per annum (table 14). When expressed in constant 1954 dollars to exclude the influence of inflation, expenditures per professional worker actually increased at the compound rate of 5.3 percent per annum.

Table 14

Expenditures per Professional Worker in Medical Research and
Rate of Increase, 1954-1960, Expressed in Current and
Constant Dollars

	<u>1954</u>	<u>1960</u>	Compound rate of increase per annum
Expenditures per professional worker in medical research (in thousands)			
Current dollars	11.7	18.0	7.5%
1954 dollars (using GNP deflator)	11.7	15.7	5.3%

However, the 1954-1960 experience scarcely reflects four predictable influences upon future expenditures per professional worker:

1. Salaries of scientific and professional manpower, especially university faculty, are likely to rise more rapidly than salaries and wages for the labor force as a whole and the practice of charging faculty time in sponsored research to research grants and contracts is likely to become increasingly prevalent. ^{1/}
2. Additional expenditures per professional worker will result from changing organizational arrangements for research. For example, we can anticipate a much higher expenditure per research worker in large scale clinical research facilities where other items represent the bulk of the cost -- patient care, supplies, equipment, and supporting services. More than 75 NIH-sponsored centers have been established to date in medical schools and hospitals. It is estimated that an additional twenty-five clinical research centers will be established this year, bringing the total to around 100, spread throughout the United States in virtually every community with a major medical school or teaching and research hospital.
3. Medical research calls increasingly for highly complex instrumentation and utilizes costly equipment essential for increasingly precise measurement and monitoring of critical data derived from experimental and clinical investigation.

^{1/} See JAMA Education Issues, November 1959 and 1961. Between 1959 and 1961, the number of full-time medical school faculty receiving 50 percent or more of their salary from Federal sources increased over one-third, from 4971 to 6644. However, the proportion of total full-time medical school faculty so supported rose only from 27 to 28 percent.

4. Large-scale, long-term population studies are also costly.

These studies operate under common research design to facilitate simultaneous and systematic observation of diverse groups and thereby to speed up the testing and verification of hypotheses about disease and human health.

While these additional expenditures are real and predictable in the broad sense, there is no way of accurately estimating the precise increase that will be involved. Accordingly, a conservative view has been taken that these four developments will add approximately 50 percent to the 1954-1960 per annum rate of increase in expenditures per professional worker. This estimate assumes that the compound rate of increase in future expenditures per professional worker, 1961-1970, will be composed of two factors: (1) The historical 1954-1960 rate of 5.3 percent (excluding the measurable influence of inflation) and (2) an additional 2.7 percent per annum to take account of the four new developments. In effect, it is estimated that these four new developments will contribute roughly one-third to the 8 percent per annum compound rate of increase in expenditures per professional worker, 1961-1970.

This assumption with respect to the probable future expenditure per professional worker in medical research has a critical influence upon subsequent estimates of future manpower requirements. If the future expenditure per professional worker is underestimated then future manpower requirements will be overstated. Conversely, if future expenditures per professional worker are overestimated, then future manpower requirements will be understated. Recognizing the critical character of this assumption, we

have (1) carefully considered the component costs involved in the 7.5 percent per annum increase, 1954-1960, (2) excluding the influence of inflation during this period, bringing the actual per annum rate of increase down to 5.3 percent, and (3) taken into account the growing significance of the four new developments as major elements in the total cost of medical research. Viewed in this light, the 8 percent per annum estimate may be unduly conservative. On balance, however, tested against the criteria of reasonableness and probability, it is believed to provide a sound basis for estimating future manpower requirements.

Future Manpower Requirements for
Medical Research, 1970

In accordance with the assumptions discussed above, it is assumed that (1) expenditures will increase from \$18,000 to \$39,000 per professional worker and (2) the number of professional medical research workers needed by 1970 will approximate 77,000.

1. \$18,000		8 percent per annum		\$39,000 estimated
Expenditure per		rate of increase in		expenditure per
Professional	X	expenditure per pro-	=	professional worker
Worker in 1960		fessional worker in		in 1970.
		10 years,		
		1961-1970		

2. Therefore, $\frac{\$3,000,000,000}{\$39,000} = 77,000$ professional workers needed to carry out the Nation's medical research effort by 1970.

3. Accordingly, the estimate of 77,000 professional workers is being used to represent manpower requirements for 1970.

Thus, by 1970, each additional \$1 million in national expenditures for medical and health-related research will require an additional 26 professional workers -- less than half of the 55 professional workers currently needed for each additional \$1 in research expenditures.

Summary

1. The simplest method of estimating manpower requirements for medical research in 1970 is to divide total research expenditures by expenditures per professional worker.
2. Expenditures per professional worker in medical research increased at a compound rate of 7.5 percent per annum, 1954-1960.
3. Adjusted to exclude inflationary influences, expenditures per professional worker actually increased at the compound rate of 5.3 percent per annum, 1954-1960.
4. Expenditures per professional worker probably will continue to rise during the Sixties, reflecting that:
 - a. Faculty salaries are rising more rapidly than over-all salaries and wages.
 - b. The practice of charging faculty-time in sponsored research to the grants and contracts will become more prevalent.
 - c. The operation of large-scale clinical research facilities will entail higher expenditures per professional worker.
 - d. Greater use of more complex, automated, and precise instrumentation and other costly research equipment will also contribute to increasing expenditures per professional worker.
 - e. Higher costs involved in the operation of large-scale, long-term population studies.

5. It is assumed that these new developments will add approximately 50 percent to the 1954-1960 per annum rate of increase in expenditure per professional worker. This assumption is a critical one. The range of probable error is wide. If the rate of increase is overestimated, then manpower requirements will exceed the projection set forth above; if it is underestimated, then fewer scientists would be needed. Discussion with National Science Foundation officials and other informed sources indicates that the assumption is reasonable, but probably conservative.
6. Accepting this assumption with respect to the rising substantive costs of doing medical research, it is estimated that the per annum rate of increase in expenditure per professional worker, 1961-1970, will approximate 8 percent (excluding inflationary influences).
7. Taking these factors into account, it is estimated that expenditures will rise to \$39,000 per professional worker by 1970.
8. Therefore $\frac{\$3,000,000,000}{\$39,000} = 77,000$ professional workers needed to carry out the Nation's medical research effort by 1970.

C. Distribution of Manpower Requirements for the Future.

When projections such as these are broken down into finer and finer detail, the degree of confidence inevitably diminishes. (Automobile output may be projected with a high degree of confidence in the aggregate estimate; the degree of confidence diminishes when these projections are broken down by manufacturer, by style, by color, etc.) Nevertheless, the 1954-1960 trends, combined with the 1960 distribution by sector, by level of training, and by field of science, do suggest the directions in which the composition of manpower requirements may be expected to change between 1960 and 1970.

Assuming acceleration of prevailing trends, the distribution of manpower requirements for the future probably will reflect:

1. Higher proportion in universities, medical schools, hospitals, research institutes, and research organizations in foreign countries (See table 15 for hypothetical distribution by sector).
2. Higher proportion of doctoral trained researchers. It is estimated that the proportion of doctoral trained scientists in medical research will rise from three-fourths of the total in 1960 to four-fifths by 1970 (chart 4). Within the doctoral group, it is estimated that Ph.D.'s will rise from 45 percent to over half the total and that the proportion of M.D.'s will decline slightly from 29 to 27 percent (See table 16 for hypothetical distribution by level of training).

Table 15

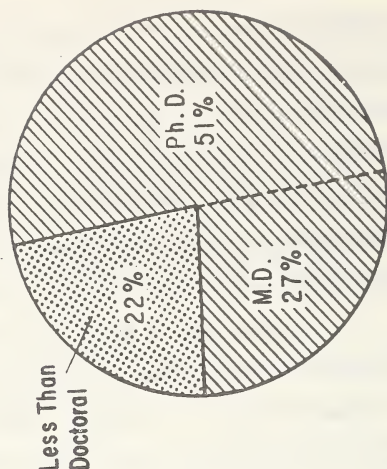
Professional Workers Engaged in Medical and Health-Related Research by Sector, 1960, and Estimated Distribution for 1970

Sector	Number		Percentage distribution	
	1960	Estimate for 1970	1960	Estimate for 1970
Total	39,700	77,000	100.0	100.0
Government	7,800	12,000	19.7	15.6
Industry	7,200	12,000	18.1	15.6
Extramural	24,700	53,000	62.2	68.8

SOURCE: National Institutes of Health.

Chart 4
MANPOWER FOR MEDICAL AND HEALTH-RELATED RESEARCH BY DEGREE
1960-1970

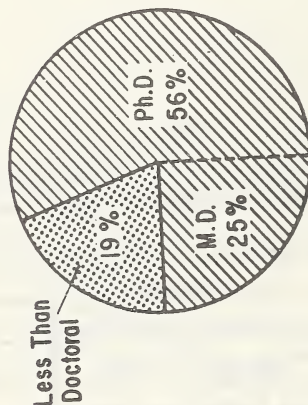
TOTAL
REQUIREMENTS
1970



77,000

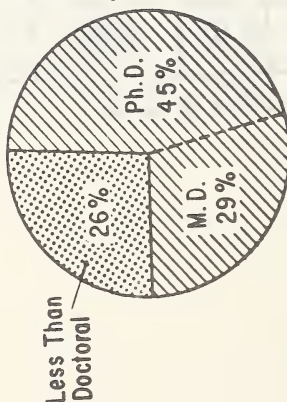
NET ADDITIONAL
REQUIREMENTS

1961-1970



45,000

1960



39,700

SOURCE: National Institutes of Health

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Table 16

Professional Workers Engaged in Medical and Health-Related Research
by Level of Training, 1960, and Requirements for 1970

Level of training	Requirements 1970	Less employment 1960	Plus attrition 1960-1970	Equals additional requirements 1961-1970
		<u>Number</u>		
Total	<u>77,000</u>	<u>39,700</u>	<u>7,700</u>	<u>45,000</u>
Doctoral	<u>60,000</u>	<u>29,400</u>	<u>5,900</u>	<u>36,500</u>
M.D., D.D.S., D.V.M.	<u>20,500</u>	<u>11,400</u>	<u>2,400</u>	<u>11,500</u>
Ph.D., Sc.D.	<u>39,500</u>	<u>18,000</u>	<u>3,500</u>	<u>25,000</u>
Less than doctoral (M.S., M.P.H., M.A., B.S., A.B.)	<u>17,000</u>	<u>10,300</u>	<u>1,800</u>	<u>8,500</u>
		<u>Percentage distribution</u>		
Total	<u>100.0</u>	<u>100.0</u>	<u>100.0</u>	<u>100.0</u>
Doctoral	<u>77.9</u>	<u>74.1</u>	<u>76.6</u>	<u>81.1</u>
M.D., D.D.S., D.V.M.	<u>26.6</u>	<u>28.7</u>	<u>31.2</u>	<u>25.5</u>
Ph.D., Sc.D.	<u>51.3</u>	<u>45.4</u>	<u>45.4</u>	<u>55.6</u>
Less than doctoral (M.S., M.P.H., M.A., B.S., A.B.)	<u>22.1</u>	<u>25.9</u>	<u>23.4</u>	<u>18.9</u>

SOURCE: National Institutes of Health.

3. Higher proportion in the sciences versus the clinical specialties but with substantial numerical increases required in the number of clinical investigators (see table 17 for hypothetical distribution by field of science).
4. Broader distribution among the fields of sciences participating in and contributing to the medical and health-related research.
5. Increasing specialization of the research function and rising recognition of research as a full-time socially useful career.
6. Anticipation of rising needs in rapidly growing disciplines such as biophysics, genetics, immunochemistry, biomathematics, and neurophysiology -- with an attraction into these fields of biologists, physicists, chemists, mathematicians, and clinicians -- in advance of the new generation bearing the discipline label.
7. Complementary and sharply rising requirements for well-trained, highly-skilled technicians, especially as complex instrumentation and precise controls become increasingly significant factors in medical research. This analysis of scientific manpower requirements does not cover technicians. There is, however, a general consensus that action is needed to ensure that the growth of medical research is not retarded by an inadequate supply of well-trained technicians.

It should be cautioned that the estimates set forth by sector, level of training, and field of science in Tables 15, 16, and 17 are suggestive rather than definitive. Many diverse forces are likely to influence this pattern during the decade ahead. Among the forces are:

1. The rapid growth in number and different kinds of organizations engaged in medical research;
2. The growing relevance of more and more fields of science for the advancement of medical research, with increasing emphasis upon greater depth of fundamental inquiry on the one hand and greater breadth of interest on the other;
3. The rising emphasis upon reducing the lag between new knowledge and therapeutic application;
4. The shifting employment pattern of the medical profession in a manner that may afford M.D.'s increased opportunities for clinical research; and
5. The increasing prevalence of post-Ph.D. training in the science fields.

Table 17

Professional Workers Engaged in Medical and Health-Related Research
by Field, 1960, and Estimated Distribution for 1970

Field	Number			Percentage Distribution		
	1960	Estimate for 1970	Increment required	1960	Estimate for 1970	Increment required
Total	<u>39,700</u>	<u>77,000</u>	<u>37,300</u>	<u>100.0</u>	<u>100.0</u>	<u>100.0</u>
Clinical specialties ^{1/}	10,915	21,000	10,085	27.5	27.3	27.0
Biosciences	17,160	31,500	14,340	43.2	40.9	38.5
All other sciences ^{2/}	11,625	24,500	12,875	29.3	31.8	34.5

SOURCE: National Institutes of Health.

^{1/} Includes dentistry, osteopathy, and veterinary medicine.

^{2/} Includes physical sciences, mathematics, engineering, social and behavioral sciences and the health professions.

D. Sources of Supply to Meet Net Requirements for 1970.

It is estimated that about 40,000 professional workers were engaged in medical research in 1960. How many will still be involved in medical research in 1970? Normal losses may be anticipated through death, retirement, and shifts to other activities. To estimate losses through death or retirement, we have weighted life table rates by the approximate age distribution of manpower currently engaged in medical and health-related research. This results in an attrition rate of 8.4 percent, roughly 3,350 losses through death. It has been estimated that an equal number of scientists will move out of medical research into other activities by 1970, with an additional 1,000 lost through retirement -- bringing total attrition to 7,700.

Consequently, this assumes that nearly 20 percent of the 40,000 professional workers currently engaged in medical research will need to be replaced by 1970. Death and retirement can be predicted with some degree of certainty but movement out of medical research into other activities necessarily represents a judgmental estimate. Consequently, if the actual movement of medical researchers into other activities exceeds this estimate, the additional number needed by 1970 would increase accordingly.

Thus, it should be emphasized that the assumptions both with respect to expenditures per professional worker and replacement needs are subject to a wide range of error.

With these qualifications in mind, it is estimated that net additional manpower requirements will approximate 45,000 professional workers, fully qualified to engage in medical research as independent investigators by 1970 (table 18).

Table 18

Net Manpower Requirements for 1970, Taking into Account Estimated Attrition Through Death, Retirement, and Movement into Other Activities

	<u>Number</u>
Requirements for 1970	77,000
Less Employment, 1960	<u>39,700</u>
	37,300
Plus Attrition through Death, Retirement, and Movement into Other Activities	<u>7,700</u>
Equals Net Additional Requirements, 1961-1970	45,000

The potential supply for this additional increment of 45,000 must be drawn from five sources:

- (1) the pool of those now qualified but not participating in medical research;
- (2) the pool of those who have received their M.D. or Ph.D. degrees during the past decade and are now either receiving postdoctoral research training or working as research assistants or research associates;
- (3) those now enrolled in graduate school or medical school -- this group will enter the research labor force during the middle and late Sixties; and
- (4) those already enrolled in college--of this group, those who go on for graduate or professional training may be expected to enter the research labor force no earlier than 1967. However, this component will become increasingly critical by 1970 and will comprise the basic pool for the 1970-1975 period.

(5) foreign-trained scientists conducting research either in the United States or in foreign countries.

It is obvious, then, that a simple comparison between M.D. and Ph.D. output projections, 1961-1970, and manpower needed for medical research during this same period will not suffice because a considerable proportion of those receiving such doctoral degrees after 1965 will not enter the research manpower pool as independent investigators until after 1970.

This calls for a more careful and sophisticated analysis of the nature of the flow of independent investigators into the medical research manpower pool. Accordingly, the analysis in the two sections to follow deals first with the flow of scientific manpower into medical research and secondly, with the projected output of M.D.'s and Ph.D.'s, 1961-1970. While this latter group will contribute to the supply of researchers, 1966-1970, it is crucial for the years beyond.

V. THE FLOW OF PROFESSIONAL WORKERS INTO THE MEDICAL RESEARCH
MANPOWER POOL, 1961-1970

The growth of medical research generates a demand for more trained researchers. In the early years, research growth acted like a sponge, absorbing into research activity many scientists who had never dreamed of opportunities on a scale made possible through the rapid but steady growth over the past 15 years. Thus, the supply of well-qualified investigators has been and will continue to be the primary strategic factor influencing the growth of medical research.

This factor is more critical for research than for other functions because:

- (1) the manpower pool is restricted to a highly specialized group,
- (2) the possibility of improving utilization through job dilution or substitution of lesser skills is limited,
- (3) extensive preparation is required to meet exacting standards,
- (4) the training period is long -- from 5 to 10 years beyond the bachelor's degree, and
- (5) creative talent is scarce and only a portion of those adequately trained will be motivated toward research, and
- (6) there is a considerable lag between completion of formal academic preparation for the M.D. or Ph.D. degree and entrance into the medical research manpower pool as an independent researcher.

This last consideration is crucial in examining the flow of well-qualified investigators into the medical research manpower pool because (1) doctoral-trained manpower now comprise 75 percent of those actively engaged in medical research and (2) it is estimated that this proportion will rise to 90 percent by 1970, taking into account the growing involvement of Ph.D.'s and M.D.'s in medical research. The supply of doctoral-level manpower serving as new principal investigators is drawn from those who have been serving as co-investigators and research associates; men from 3 to 10 years past their formal Ph.D. or M.D. training. As new people move into the independent investigator supply, their numbers are replenished by postdoctoral and post professional fellows and trainees moving up the research career ladder. Their numbers in turn are replenished by younger postdoctoral and predoctoral fellows stepping into responsible research assistant slots. Consequently, for the short run, 1965, we must depend largely but not exclusively upon those who have already completed the formal requirements for their M.D. or Ph.D. degrees.

It is assumed that the vast majority of independent investigators will flow into the pool within 15 years after receipt of the doctoral degree. If this seems unduly long, it must be recognized that the normal post-M.D. preparation involves a minimal period of 4 years, 1 year of internship and 3 of residency training. Military service may add several additional years. Postdoctoral research training, while it further defers entrance into the research manpower pool as a fully-qualified independent investigator, provides the research experience and training requisite for more productive inquiry. Thus, the M.D. desiring to do medical research is likely to enter the manpower

pool, with the capability of carrying out research at the level of an independent investigator, sometime between 5-15 years after completion of his medical school training. In the interim, of course, he will have participated as a research assistant or research associate before (1) seeking support in his own right in the arena of national competition or (2) joining as a collaborator in a more highly organized research enterprise.

The Ph.D. in the sciences relevant to medical research can be expected to spend a minimum of two years in postdoctoral training, followed by additional experience and training as a research assistant or research associate before entering the medical research manpower pool as a fully trained independent investigator.

Thus, for all practical purposes, M.D.'s and Ph.D.'s who received their degrees, 1946-1960, constitute the medical research manpower pool between now and 1965.^{1/}

The flow of professional workers into the medical research manpower pool can be simulated through the use of models that: (1) take into account the total number available, (2) estimate the proportion that will engage in medical research, (3) phase the entrance into the research manpower pool of each cohort or class over a 10-15 year period after receipt of M.D. or Ph.D. degree, and (4) make assumptions about the additional number of scientists trained abroad and conducting medical research either in the U. S. or in a foreign country.

The models demonstrate that (1) new entrants flowing into the research manpower pool in any one year are drawn from Ph. D.'s and M.D.'s who have been trained from 3 to 15 years before and (2) the long-term pay-off of

^{1/} See Appendix table 5.

today's fellowship and training programs shows up in the enlarged supply and sharpened skills of tomorrow's researchers.

To illustrate the flow into the medical research manpower pool, models have been prepared for three groups -- M.D.'s and Ph.D.'s in the biological sciences and psychology -- that now comprise roughly 80 percent of the doctoral-trained manpower in medical research (See Appendix tables 6-10) that illustrate the year-by-year flow and set forth sources and assumptions in detail.

It should be emphasized that (1) these models are artificial constructs and (2) the precise numbers shown in the year-by-year flow of new entrants into medical research depend heavily upon the validity of the assumptions used. The crucial assumption is that a rising proportion of M.D.'s and Ph.D.'s, already trained and those who will complete formal training by 1965-1967, will participate in medical research in the decade ahead. This, in turn, depends upon (1) sustained expansion of research training opportunities both at postdoctoral and predoctoral levels and (2) continued enlargement of support for research and for the construction of research and related facilities.

A. Trends in M.D. Participation in Medical and Health-Related Research

M.D.'s presently engaged in research constitute but a small fraction of the total M.D. population. It is estimated that 11,000 M.D.'s were engaged at least part-time in research in 1960. This amounts to about 4 percent of the 252,000 M.D.'s in 1960. However, two developments over the past decade suggest that the proportion of M.D.'s engaged in research will increase during the Sixties: (1) rising participation of M.D.'s in research and teaching and (2) changing career aspirations of our younger physicians.

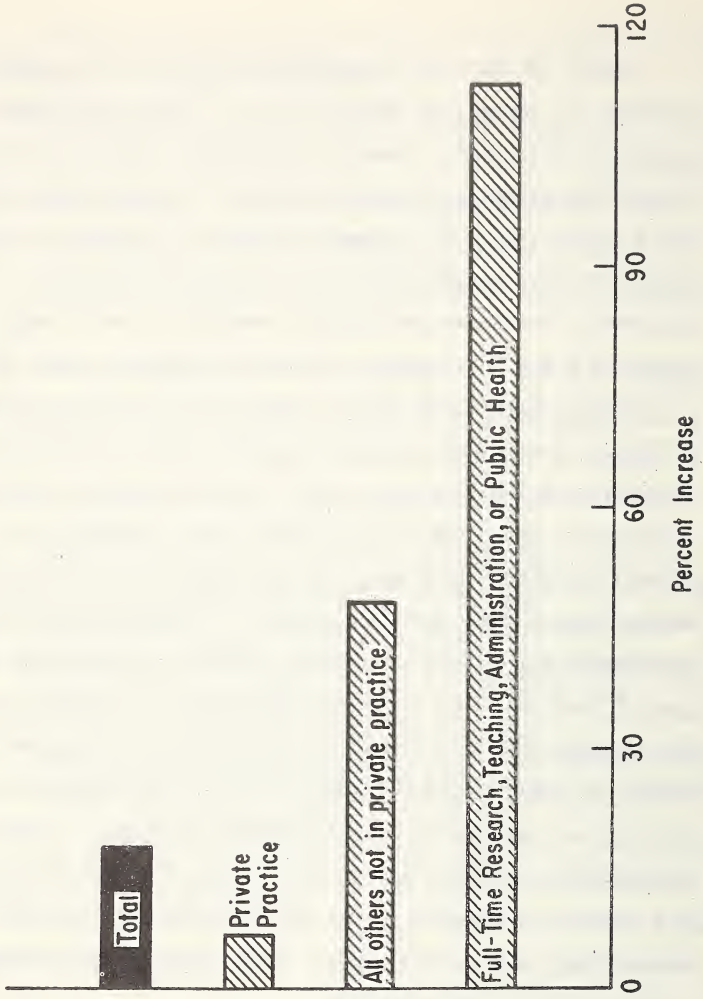
Between 1949 and 1959, the total number of M.D.'s in the United States increased 17.5 percent; the number of M.D.'s in research and teaching rose 112 percent (chart 5).^{1/} These data considerably understate the actual numerical and percentage increases for M.D.'s in research because they do not include those M.D.'s engaged in research but employed in hospitals, Federal and State research installations, industry, and group practice. Nevertheless, the comparison adequately demonstrates that a rising proportion of M.D.'s is engaged in research (See Appendix table 11).

Recent studies provide further evidence of the growing attraction of clinical investigation and academic medicine for our younger physicians. The Division of Medical Sciences, National Research Council, sent questionnaires to more than 3,000 of the 1957-58 internes, residents, and clinical trainees of the primary teaching hospitals of all United States medical schools. Approximately two-thirds of the internes and residents wanted additional training in research regardless of their future career plans.^{2/} Only 245 in the interne-resident group, or 7.5 percent, indicated that they did not want to participate in teaching or research once they entered upon their careers. In addition, 810 or 24.8 percent wanted careers in full-time or essentially full-time academic positions. Of those who wanted advanced research training, about 55 percent wished to qualify for Ph.D. degrees, if financial support were available, and 45 percent desired advanced study in scientific subjects in the fields of the biosciences, chemistry, physics, and mathematics.

^{1/} Health Manpower Source Book, PHS Pub. No. 263, section 10, Table 1, p. 2, 1960. See Appendix table 11 .

^{2/} Cain, Arthur S., Jr., and Bowen, Lois G., "The Role of Postdoctoral Fellowships in Academic Medicine," Journal of Medical Education, 36:1361, October 1961, part 2, section IV.

Chart 5
PERCENT INCREASE IN TYPE OF ACTIVITY
OF PHYSICIANS, 1949-1959



SOURCE: American Medical Directory

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Another study of internes from the 1959 and 1960 senior classes of 28 representative medical schools presents data that further confirm this shifting pattern of career aspirations.

Table 19
Career Plans of Interns From Selected
High and Low Research Emphasis Schools

Career plans	High research schools (N= 16)		Low research schools (N = 12)	
	1959	1961	1959	1961
General practice	13.5%	12.6%	30.3%	23.2%
Specialty practice	46.5	40.3	49.6	50.7
Specialty practice plus research and teaching	32.9	39.4	17.8	21.4
Research and teaching	3.0	5.6	0.7	2.0
Other	3.1	1.8	1.4	2.4
No response	1.0	0.3	0.2	0.3
Total	100.0%	100.0%	100.0%	100.0%
Number of interns	572	1165	443	981

SOURCE: Table 3.4 in STUDENTS AND CURRICULUM Section of 1961 AAMC
Institute Workbook. (Unpublished data covers AAMC Longitudinal
Study schools only.)

As indicated in table 19, a considerable proportion of the interns plan to combine specialty practice with research and/or teaching. A lesser proportion plan for careers in research and academic medicine, without specialty practice. While these expressions of intent do not constitute precise predictions of the type of activity in which this group will be engaged 5 and 10 years hence, they point toward rising involvement of M.D.'s in medical research.

Many factors contribute to this changing pattern of career aspirations.

1. Organization of health services. Increasingly, specialty practice is concentrated in medical center complexes, many of which are operated or guided by medical schools.
 2. The prestige of clinical investigation is rising.
 3. The availability of specialized facilities for clinical investigation is rising.
 4. The disparity is narrowing between net income of clinical investigators and practitioners.
- B. The Flow of M.D. s Into the Medical Research Manpower Pool, 1961 - 1970

These trends in M.D. research participation and rising interest in research-teaching careers have been taken into account in the basic assumptions used to construct the detailed models shown in Appendix tables 6A and 6B. That is, it has been assumed that the proportion of M.D.'s entering research will increase from 6 percent of the class of 1945,^{1/} to 8 percent of the class of 1950, to 12 percent of the class of 1955 and 15 percent of the class of 1960.

^{1/} Weiskotten, H.G. and Altenderfer, Marion E., "Trends in Medical Practice", Journal of Medical Education, Vol. 31, No. 7, Table 24, p. 70 (July 1956, Part 2).

What are the consequences of these assumptions for

- (1) the flow of M.D.'s into research, 1961-1970,
- (2) the staffing of new medical schools, and
- (3) the total supply and distribution of physicians required to meet the health needs of the Nation?

The Flow of M.D.'s into Research, 1961-1970

Table 20 traces the flow of four classes (1950, 1955, 1960, and 1965) into the medical research manpower pool, 1955-1979. In illustrating the flow of these four classes, it has been assumed that:

1. The percent of M.D.'s entering research will rise from 8 percent of the class of 1950 to 15 percent of the class of 1960.
2. There is a minimum 5-year lag after graduation (for internship, residency, military service, and postdoctoral research training and experience) before entering into independent research;
3. All those entering into research will do so between the 6th and 15th year following graduation.
4. Foreign input equals 20 percent of total number of M.D.'s entering research.^{1/} (This assumption with respect to foreign input includes three groups: (1) U.S. citizens who receive their medical education abroad, (2) M.D.'s who are not U.S. citizens at the time they receive their medical education in a foreign country but subsequently take up residence in the United States, and (3) foreign citizens trained as M.D.'s outside the U.S. who engage in research supported by either public or private funds included in the Nation's total expenditures for medical research.)

^{1/} This estimate is corroborated by the findings of the NIH First-Time Grantee Studies 1950, 1954, 1958, 1960.

Thus, the class of 1950 became available as medical research manpower no earlier than 1955. It is likely that virtually all of those from the class of 1950 desiring to engage in medical research will have done so by 1965; some will continue in this activity for the major portion of their careers; others will conduct research for a shorter period and then concentrate on practice, administration, teaching, and other non-research activities.

The class of 1955 spent 1956 in internship; most of those who ultimately might enter medical research will spend a minimum of 2 years, more likely 3-4 years, in residency training followed by 1-2 years of postdoctoral research training. Thus, the first trickle from this class will not have entered the pool until 1960 at the earliest. Similarly, the class of 1960 which spent last year in internship and is now in residency training will not enter the pool until 1965. By 1970, however, it is probable that all of those from 1955 or prior classes will have entered the pool.

Table 20

Model for Illustrating Flow of M.D.'s Entering Medical Research Manpower Pool. 1955-1979 from Classes of 1950, 1955, 1960 and 1965

Year of graduation	No. of M.D. degrees awarded	Total of M.D.'s entering medical research 1955-1979 from classes of 1950, 1955, 1960 and 1965	Years				
			1950-1954	1955-1959	1960-1964	1965-1969	1970-1979
Class of 1950	5553	444	---→	333	111	////	///
Class of 1955	6977	935	////	---→	727	208	///
Class of 1960	7081	1060	////	////	---→	795	26
Class of 1965	7500	1125	////	////	////	---	112
Total entering research from above four classes	---→	3564	---→	333	838	1003	139
Plus foreign input	---→	891	---→	83	210	251	34
Grand total	---→	4455	---→	416	1048	1254	173

SOURCES: M.D. Graduate of Classes of 1950, 1955, and 1960 from JAMA, Vol. 178 (Nov. 11, 1961), p. 647 (table 14). Projection for Class of 1965 from Physicians for a Growing America, PHS Publication No. 709, p. 3, 1959.

The class of 1965 entered medical school as freshmen last Fall, September 1961. These young men and women can look forward to entering the medical research manpower pool in 1970 at the very earliest. The opportunities for research experience, the nature of their medical education, and the character of their training are bound to influence their career aspirations and research interests. While this year's freshmen class will not enter research until 1970, it will add more than 1,100 independent investigators to the medical research manpower pool during the 1970's.

Table 20 illustrates:

1. The long lag between attainment of the M.D. degree and entrance into research.
2. The effect of the projected increase in the number of M.D.'s entering research, beginning with roughly 450 for the class of 1950 and rising to over 1,000 for the class of 1960 and over 1,100 for the class of 1965.

This analysis has been carried through to project the flow and total input from each medical school class that will influence the additional supply of M.D.'s in medical research, 1961-1970 (Appendix tables 6A & 6B). This projection indicates that the net increment of M.D.'s entering the medical research manpower pool may slightly exceed 11,000 during the decade -- an average of 1,100 per year.

Staffing of New Medical Schools

One of the critical issues facing the Nation during the next ten years will be the staffing of new medical schools. Both the Bayne-Jones^{1/} and Bane^{2/} Reports recommended the establishment of about twenty new medical schools by 1975. Seven new schools have already announced their program plans or received legislative authorization.^{3/}

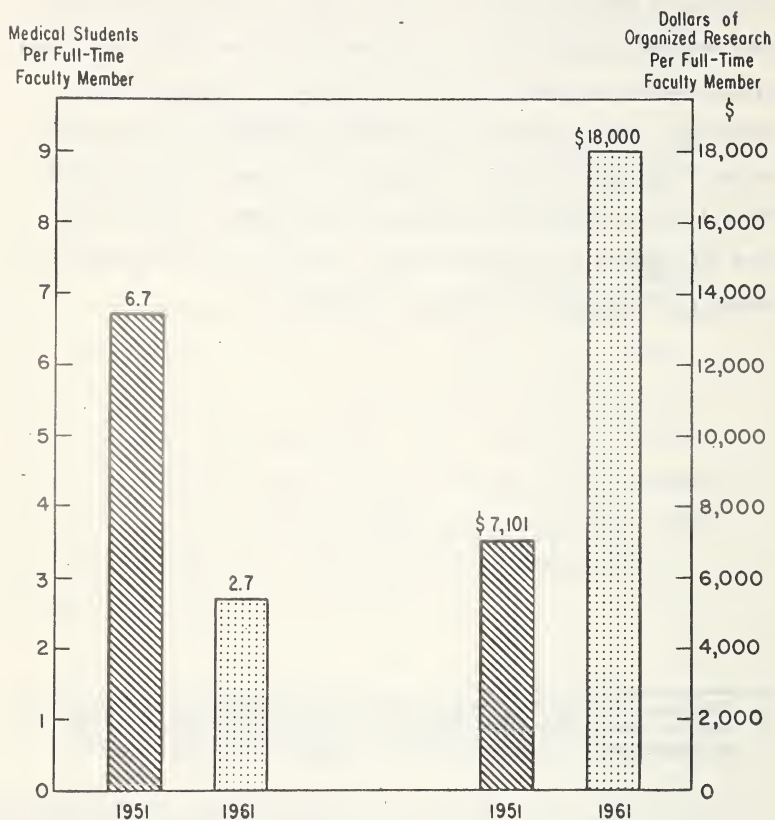
The staffing of new medical schools presents faculty needs above and beyond those who may choose to engage part-time in research. This is especially true for certain clinical fields where the combination of limited supply and high economic returns make it difficult for a young man to commit himself to academic medicine. Nevertheless, the estimates shown in the flow models of M.D.'s entering research, 1961-1970, also reflect substantial, additional staff for the teaching of physicians, research, and research training in these new schools. This is believed to be the case because, as reported in a recent survey of the new schools established during the Fifties, deans recruiting new faculty for modern medical centers seek out and demand creative teacher-investigators imbued with a high research orientation.

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- ^{1/} The Advancement of Medical Research and Education. Final Report of the Secretary's Consultants on Medical Research and Education. Office of the Secretary, Department of Health, Education and Welfare, June 27, 1958.
- ^{2/} Physicians for a Growing America. Report of the Surgeon General's Consultant Group on Medical Education. Public Health Service Publication, 709, 1959.
- ^{3/} Brown, Rutgers, Arizona, California, Connecticut, New Mexico, and Texas.

But will this rising research involvement of M.D.'s on medical school faculties divert their energies from teaching or diminish faculty contact with medical students? Experience over the past decade shows that the student/faculty ratio in medical schools has actually decreased simultaneously with rising research expenditures per faculty member (chart 6). This suggests that the research opportunities which have helped to attract M.D.'s into the academic environment have permitted the reduction of the teaching load per faculty member. Many contend that this pattern of increased research activity has also increased the quantity and enhanced the quality of teaching. ^{1/}

^{1/} Handler, Philip, "Resolved, That the Growing Emphasis on Research by Faculty and Students Has Distinctly Improved the Medical Education of Undergraduates in Medical Schools." JAMA 176:765, June 3, 1961.

NUMBER OF MEDICAL STUDENTS AND ORGANIZED RESEARCH
EXPENDITURES PER FULL-TIME FACULTY MEMBER,
1951 AND 1961



SOURCES: Enrollment: JAMA, 178: 647.

Faculty: 1951- Diehl, West and Barclay, Journal of Medical Education,
Vol. 27, Pt. I, p. 234; 1961 - JAMA, 178: 591.

Research Expenditures: 1951 - National Institutes of Health; 1961 - JAMA, 178: 587.

Impact upon the Total Supply of Physicians
To Meet the Health Needs of the Nation

It is estimated that approximately 11,000 additional M.D.'s will enter research, 1961-1970. What impact is this likely to have upon the total supply of physicians?

Over the long-run, the only adequate answer to this question is to expand the total supply to meet the Nation's total health needs for medical care, teaching, and research. The following observations, however, are pertinent to a serious consideration of the short-run implications.

1. Assuming that 11,000 new M.D.'s enter research, 1961-1970, the proportion of M.D.'s in research and teaching to all physicians probably will rise from 4 percent in 1960 to more than 6 percent by 1970.
2. In 1960, nearly four-fifths of the M.D.'s in research were located in universities and research institutes (See table 10, p. 24). Virtually all the M.D.'s in research in this sector were either full-time members of the clinical faculties of medical schools or staff in independent teaching and research hospitals. Of the remaining one-fifth, all but 5 percent were employed in Federal and State hospitals and health agencies.
3. Most of the M.D.'s engaged in research in medical schools and in non-Government and Government hospitals also teach medical students, instruct internes, and supervise the training of residents and postdoctoral fellows.

4. Most of these M.D.'s also render a wide range of health services in the inpatient and outpatient programs administered through the modern medical centers affiliated with medical schools or operated by Federal and State agencies.
5. In brief, M.D.'s engaged part-time in research also perform teaching and service functions. Thus, the entrance into research of an estimated 11,000 M.D.'s, 1961-1970, does not represent a corresponding diversion from medical care and teaching activities.

C. Input of D.O.'s, D.D.S.'s, and D.V.M.'s into the
Medical Research Manpower Pool 1/

While flow models can be used to simulate the entrance of M.D.'s and Ph.D.'s into research, comparable data are not available for D.D.S.'s, D.V.M.'s and D.O.'s. Nevertheless, members of each of these professions now engage in medical research and it is reasonable to assume that this number will grow in the decade ahead. Consequently, it is necessary to estimate the probable input from these professions into medical research, 1961-1970.

Between 1951 and 1960, approximately 43,000 degrees were awarded in these professions; the best available estimates suggest that approximately 48,000 will be awarded, 1961-1970, (table 21). The annual average for this 20-year period will approximate 4,500. If it is assumed that about 2.5 percent of each year's output participates in medical research at least on a part-time basis sometime during their careers, this would add another 100-120 doctoral-trained clinical investigators annually, 1961-1970.

Table 21

Output of D.O.'s D.D.S.'s and D.V.M.'s from U.S. Schools,
Five Year Intervals, 1946-1960, and Projections to 1970

Year Group	Total	D.O.	D.D.S.	D.V.M.
Output 1946-60	54,979	5,623	41,254	8,102
1946-50	11,893	1,108	10,785	NA
1951-55	21,133	2,224	14,915	3,994
1956-60	21,953	2,291	15,554	4,108
Projections 1961-70	48,227	5,009	34,586	8,632
1961-65	23,551	2,444	16,881	4,226
1966-70	24,676	2,565	17,705	4,406

SOURCE: 1946-60 - D.O.'s, D.D.S.'s, Public Health Service
Health Manpower Source Book - section 9; D.V.M.'s,
American Veterinary Medical Association. Projections
1961-70, National Institutes of Health.

1/ Reliable estimates on current research participation of podiatrists, chiropodists, optometrists, and pharmacists are not available. Consequently, the research manpower projections do not include these health professions.

D. Participation of Ph.D.'s in the Biosciences and Psychology in Medical and Health-Related Research.

As of 1960, there were about 26,000 Ph.D.'s in the biosciences and 10,000 in psychology in the United States. ^{1/} The basic medical science group -- anatomy, biochemistry, biophysics, microbiology, pathology ^{2/}, pharmacology, and physiology -- comprised slightly over half of the bioscience Ph.D. universe. The other biological sciences ranging alphabetically from botany through zoology constitute the other half. Clinical psychology constitutes the largest discipline within the many specialized fields of psychology.

^{1/} These totals incorporate three groups: 1) Ph.D.'s reporting to the National Science Foundation Register of Scientific and Technical Personnel obtained from a duplicate deck of punch cards furnished to the National Institutes of Health by NSF, 2) An additional 9,100 Ph.D.'s added to provide full coverage based upon the National Research Council's series of Ph.D.'s awarded in the sciences by discipline, and 3) Ph.D.'s awarded by discipline, 1957-1960, as reported to the National Institutes of Health by the National Research Council.

^{2/} Most pathologists are M.D. trained and certified by the National Board of Pathology. Those with Ph.D.'s comprise a comparatively small number -- primarily experimental pathologists.

Table 22

Distribution of Ph.D.'s in Biosciences and Psychology,
by Discipline, 1960

Field and discipline	Number	Percent
Biosciences	<u>25,962</u>	<u>100.0</u>
Basic medical sciences	<u>13,124</u>	<u>50.5</u>
Anatomy	1,432	5.5
Biochemistry	3,586	13.8
Biophysics	476	1.8
Microbiology	3,393	13.1
Pathology	260	1.0
Pharmacology	1,427	5.5
Physiology	2,550	9.8
Other biosciences	<u>12,838</u>	<u>49.5</u>
Botany	2,373	9.2
Ecology	592	2.3
Entomology	1,662	6.4
Genetics	1,565	6.0
Hydrobiology	245	1.0
Nutrition	2,135	8.2
Plant pathology	1,306	5.0
Zoology	2,444	9.4
General and other biology	516	2.0
Psychology	<u>10,312</u>	<u>100.0</u>
Clinical	3,450	33.5
Counseling and guidance	995	9.6
Educational	835	8.1
Experimental, comparative, physiological	1,840	17.8
Industrial and personnel	728	7.1
Social	741	7.2
All other	1,723	16.7

SOURCE: NSF National Register of Scientific and
Technical Personnel 1956-58 data expanded by
NIH to provide 100 percent coverage and
supplemented by NRC Ph.D. output data 1957-60.

What are the critical characteristics of this pool of Ph.D. trained scientists?

1. Youth and recency of training. Roughly 43 percent of the 26,000 bioscientists are under 35 years of age; 60 percent are under 40. Approximately 22 percent of the total received their degrees 1957-1960; 63 percent of them have received their degrees since the close of World War II.
2. High research orientation. Nearly ninety (89) percent of the basic medical scientists are engaged in research either as a primary or a secondary activity. The other bioscientists have almost as high a research participation (84 percent), but a smaller percentage report research as a primary activity.

Table 23

Ph.D. Bioscientists and Psychologists Whose Primary or Secondary Activity Is Research, 1960

Field	Total Ph.D.'s	Percent of Ph.D.'s reporting research as primary or secondary activity		
		Total	Primary	Secondary
Biosciences	100	86	57	29
Basic medical sciences	100	89	61	28
Other biosciences	100	84	53	31
Psychology	100	46	25	21

SOURCE: Deck of punch cards on NSF National Register of Scientific and Technical Personnel, 1956-58, made available to NIH for special analysis.

3. About 70 percent of the bioscientists are employed in universities and research institutes, nearly 65 percent of them in colleges and universities. This high concentration tends to hold for the psychologists as well, with the exception of clinical psychologists, nearly half (46 percent) of whom are employed in Federal and State hospitals and mental institutions.

Table 24

Percent Distribution of Ph.D.'s in the Biosciences and Psychology
by Discipline and Type of Employer, 1960

Field and discipline	Total	Educational & other non-profit institutions			Government			Industry
		Total	Educ. Inst.	Non-Profit	Total	Federal	State & local	
Total biosciences	100.0	71.2	64.4	6.8	16.1	13.7	2.4	12.7
Basic medical sciences	100.0	68.0	59.3	8.7	15.1	12.9	2.2	16.9
Anatomy	100.0	93.6	90.7	2.9	3.8	3.5	0.3	2.6
Biochemistry	100.0	67.3	52.5	14.8	16.1	14.1	2.0	16.6
Biophysics	100.0	63.5	55.2	8.3	26.0	24.5	1.5	10.5
Microbiology	100.0	57.1	50.4	6.7	19.6	15.3	4.3	23.3
Pathology	100.0	68.6	45.5	23.1	18.6	14.7	3.9	12.8
Pharmacology	100.0	53.1	48.2	4.9	13.6	12.0	1.6	33.3
Physiology	100.0	79.0	71.9	7.1	12.3	11.4	0.9	8.7
Other biosciences	100.0	74.5	69.8	4.7	17.2	14.5	2.7	8.3
General biology	100.0	96.9	95.8	1.1	1.1	1.1	-	2.0
Botany	100.0	81.5	77.7	3.8	12.7	11.7	1.0	5.8
Ecology	100.0	86.1	83.4	2.7	11.9	8.9	3.0	2.0
Entomology	100.0	63.7	61.0	2.7	25.6	20.2	5.4	10.7
Genetics	100.0	76.0	69.5	6.5	18.0	16.6	1.4	6.0
Hydrobiology	100.0	79.5	73.7	5.8	17.6	8.8	8.8	2.9
Nutrition	100.0	68.3	60.0	8.3	13.9	12.1	1.8	17.8
Plant pathology	100.0	57.6	54.5	3.1	30.3	25.4	4.9	12.1
Zoology	100.0	84.0	80.0	4.0	12.4	10.1	2.3	3.6
Biology, other	100.0	62.7	53.0	9.7	26.9	25.4	1.5	10.4
Psychology	100.0	61.8	54.5	7.3	25.0	17.4	7.6	13.2
Experimental, comparative and physiological	100.0	71.4	65.2	6.2	16.9	15.2	1.7	11.7
Social	100.0	77.1	68.0	9.1	14.8	12.0	2.8	8.1
Clinical	100.0	40.5	31.6	8.9	45.5	28.0	17.5	14.0
Counseling & guidance	100.0	76.4	71.0	5.4	18.2	14.5	3.7	5.4
Industrial & personnel	100.0	34.9	27.3	7.6	13.7	12.8	0.9	51.4
Educational	100.0	89.5	85.4	4.1	6.7	4.3	2.4	3.8
All other	100.0	77.0	70.0	7.0	14.1	10.7	3.4	8.9

SOURCE: Data obtained from NSF deck of punch cards on Ph.D.'s in the National Register of Scientific and Technical Personnel, 1956-58.

Taken together, these three factors--youth, high research orientation, and high concentration in colleges and universities--characterize the current supply of Ph.D.'s in the biosciences and psychology. While comparable information is not available in the same detail for physicists, mathematicians, electronic engineers, and behavioral scientists, there is good reason to believe that their youth and research involvement approximate that of the core Ph.D. group described above.

This newly trained group has many productive years ahead; nearly two-thirds of all Ph.D.'s in these fields are under 40. Likewise, the fact that most of these Ph.D.'s are faculty members carrying on research as a part-time activity provides a highly elastic element in the manpower supply picture. This element of elasticity is crucial because a slight increase in the proportion of faculty time devoted to research can enlarge the effective medical research manpower pool.

Between 1946 and 1960, nearly 70,000 Ph.D. degrees were awarded in the sciences (see table 39, p.109). While scientists from all fields and disciplines now participate in the Nation's medical research enterprise, more than three-fourths of the Ph.D.'s are drawn from the biological sciences and psychology. The basic medical sciences represent the largest and most critical group of the Ph.D. scientists in medical research.

Here, a proud scientific tradition has shaped the evolution of medicine over the past 2,000 years, beginning with Galen in the second century A.D. Vesalius of Padua at the age of twenty-eight founded the science of anatomy with the publication of his great work in June, 1543.

A hundred years later William Harvey at the College of Physicians in London made clear the vital link between anatomy and physiology in his historic studies of blood circulation. In the mid-nineteenth century, Claude Bernard at the University of Paris published his Introduction to the Study of Experimental Medicine and conducted research in physiology and pharmacology. At about the same time, Rudolf Virchow, Director of the Pathological Institute in Berlin -- the first independent institute of its kind -- founded modern pathology. Disease, he taught, was life, though life under abnormal conditions, different from those that promoted health. He theorized that diseases arose through the working of abnormal stimuli upon the cell. Bacteriological research has, of course, supplied us with data that in many respects transcend the limits of cellular pathology--but, at the same time, represent a working out of Virchow's principles. With the work of Robert Koch and Paul Ehrlich, both Nobel prize-winners, the foundations of contemporary microbiology and biochemistry were established.

These men had many things in common. They were trained as physicians; they received extensive training in the natural sciences; they combined research with teaching and with service; they held university or independent institute faculty appointments; they were highly productive as researchers in their early years; they exercised a great influence upon their students throughout their lives.

These characteristics are almost equally-descriptive of today's basic medical scientists--with one significant exception occasioned by the growth of knowledge which always breeds increasing specialization. Today, however, the preponderance of basic medical scientists--anatomists, biochemists, biophysicists, microbiologists, pathologists, pharmacologists, and physiologists--are Ph.D. trained, and a steadily decreasing proportion seek a medical education first (the classical pattern that governed the output of basic medical scientists in the United States through the Twenties).

E. The Flow of Ph.D.'s in the Basic Medical Sciences Into the Medical Research Manpower Pool, 1961-1970

By applying the concept of the flow model, described earlier for M.D.'s (pp. 55-57), we can estimate the probable number of Ph.D.'s in the basic medical sciences, who will enter the medical research manpower pool, 1961-1970. Table 25 illustrates the flow of four cohorts (those receiving Ph.D.'s in the basic medical sciences in 1950, 1955, 1960, and 1965) into medical research, 1953-1974.^{1/} In developing this model, it has been assumed that:

1. Ninety percent of Ph.D.'s in the basic medical sciences will enter research. This corresponds with current participation (see table 23, p.66).

^{1/} See Appendix tables 7 and 9, for models of year-by-year flow into the medical research manpower pool, 1961-1970, for both the basic medical sciences and the other biological sciences.

2. There is a minimum three-year lag for postdoctoral training and research experience between receipt of the Ph.D. and entrance into independent research.
3. All those entering research will do so between the fourth and tenth year after receipt of the Ph.D. This assumes that those who enter the pool prior to the fourth year after receipt of Ph.D. probably are equal to the number who enter for the first time after their tenth year.
4. Foreign input equals 20 percent of the total number of Ph.D.'s entering medical research.^{1/} (Foreign input includes three groups: (1) U. S. citizens who go abroad for Ph.D.-level training, (2) Ph.D.'s who were not U.S. citizens at the time they received their Ph.D. training but now reside in the U. S., and (3) Ph.D.'s who receive their advanced training outside the U.S. and engage in research supported by public or private funds included in the Nation's total expenditures for medical research.)

Table 25

Model for Illustrating Flow of Ph.D.'s in the Basic Medical Sciences Entering Medical Research Manpower Pool, 1953-1974, from Classes of 1950, 1955, 1960, and 1965.

Year of graduation	No. of Ph.D. degrees awarded	Total of Ph.D.'s entering medical research 1953-1974 from classes of 1950, 1955, 1960 and 1965	Years				
			1950-1954	1955-1959	1960-1964	1965-1969	1970-1974
Class of 1950	362	326	→ 129	197	////	////	////
Class of 1955	647	582	////	→ 233	349	////	////
Class of 1960	710	640	////	////	→ 256	384	////
Class of 1965	1128	1015	////	////	////	→ 406	609
Total entering research from above four classes	→	2563	129	430	605	790	609
Plus foreign input	→	641	32	108	151	198	152
Grand total	→	3204	161	538	756	988	761

SOURCES: Ph.D. Graduates of Classes of 1950, 1955 and 1960 from the National Academy of Sciences-National Research Council. Projection for the Class of 1965 made by National Institutes of Health.

^{1/} NIH First-Time Grantee Studies -- 1950, 1954, 1958, 1960.

Table 25 shows that a total of 560 Ph.D.'s in the basic medical sciences had entered medical research by 1960 from the two cohorts of 1950 and 1955. Because the doubling of Ph.D. output over a decade enlarges the base correspondingly, the two later cohorts of 1960 and 1965 will add nearly twice as many (1,050) Ph.D.'s in the basic medical sciences to the supply of medical researchers between 1960 and 1969.

The total input into research from these four cohorts approximates 3,200-- an average of 800 per cohort. It is apparent, however, that the average input per cohort is rising steeply when one compares the anticipated input of more than 1,000 from the 1965 cohort as compared with the 325, 580, and 640 from the 1950, 1955, and 1960 cohorts respectively. This rising average mirrors steadily rising Ph.D. output.

This abbreviated analysis of four cohorts has been used to (1) illustrate the time lag between receipt of Ph.D. degree and entrance into the medical research manpower pool (2) show the probable number that will enter the supply of well-qualified independent investigators during each five-year period and (3) demonstrate that the number entering research is rising steeply in consonance with enlargement of Ph.D. output.

The more detailed, year-by-year analysis is presented in Appendix tables 7, 8, and 9. These tables trace the flow and total input from each Ph.D. cohort that will influence the additional supply of bioscientists entering medical research, 1961-1970. Drawing upon the data presented in these tables, it is estimated that the net increment of Ph.D.'s in the biosciences entering medical research, 1961-1970, could approximate 14,300.

Table 26

Estimated Net Increment of Ph.D.'s in the Biosciences Entering
Medical Research and Health-Related Research, 1961-1970

Field	Increment, 1961-1970	
	Total	Average per year
Biosciences, total	14,300	1,430
Basic medical sciences	9,000	900
Other biological sciences	5,300	530

F. The Flow of Ph.D.'s in Psychology into the Medical
Research Manpower Pool, 1961-1970.

In contrast to the basic medical sciences, where nearly 90 percent of the Ph.D.'s engage in medical research, slightly less than one-half of the Ph.D. psychologists were engaged in research, 1956-58.^{1/} The practical implications of this relationship upon the flow of research manpower are self-evident: One Ph.D. in the basic medical sciences is roughly equivalent to one new research scientist, whereas, in effect, it takes two Ph.D.'s in psychology to yield an increment of one research scientist for the medical research manpower pool.

However, well over one-half of the younger psychologists, those who received their degrees after World War II, are in research. Accordingly, in developing the flow and model for Ph.D. psychologists, it has been assumed that:

^{1/} As reported to the National Science Foundation Register of Scientific and Technical Personnel.

1. Fifty percent of the Ph.D.'s in psychology who graduated in 1950 and 1955 and 60 percent who graduated in 1960 and 1965 will enter research;
2. There is a three-year lag between graduation and entering into independent research;
3. All those entering research will do so between the fourth and eleventh year following graduation; and
4. The foreign input, while qualitatively important, is quantitatively insignificant as a factor influencing the total supply of Ph.D.'s in psychology.

Table 27 illustrates the flow of Ph.D. psychologists into medical research, 1953-1975, from four Ph.D. cohorts (1950, 1955, 1960, and 1965). Approximately, 1,700 Ph.D. psychologists will enter medical research from these four cohorts. It should be noted, however, that 700 or roughly 40 percent of this total will come from the cohort of 1965, most of whom began their graduate training this year.

Table 27

Model for Illustrating Flow of Ph.D.'s in Psychology Entering Medical Research Manpower Pool, 1953-1975, from Classes of 1950, 1955, 1960 and 1965

Year of graduation	No. of Ph.D. degrees awarded	Total of Ph.D.'s entering medical research 1953-1975 from classes of 1950, 1955, 1960 and 1965	Years				
			1950-1954	1955-1959	1960-1964	1965-1969	1970-1975
Class of 1950	348	174	→ 26	131	17///	///	///
Class of 1955	729	365	///	→ 54	274	37///	///
Class of 1960	761	457	///	///	→ 69	342	46///
Class of 1965	1166	700	///	///	///	→ 105	595
Total entering research from above four classes	→	1696	26	185	360	484	641

SOURCES: Ph.D. Graduates of Classes of 1950, 1955 and 1960 from the National Academy of Sciences-National Research Council. Projection for the Class of 1965 made by National Institutes of Health. (See Appendix table 17).

Appendix tables 10A & 10B trace the year-by-year flow and estimated net input of Ph.D. psychologists into the medical research manpower pool, 1961-1970. Drawing upon these tables, it is estimated that the net increment of Ph.D. psychologists into medical research could exceed 4,300 during this period, averaging 430 per year, with the input between 1966 and 1970 rising from 420 to nearly 600 -- more than a 40 percent increase.

G. Input of Ph.D.'s in Other Science Fields Into Medical Research Manpower Pool, 1961-1970.

Accepting the flow models as a rough approximation of the probable number of Ph.D.'s in the biosciences and psychology that will enter medical research, this results in a total of 18,600 new entrants, 14,300 in the biosciences and 4,300 in psychology. Total additional Ph.D. requirements for 1970 have been estimated at 25,000 (see table 16, p. 41). This means that an additional 6,400 Ph.D.'s from all other fields of science will need to enter medical research, 1961-1970, if these requirements are to be met. What are the prospects that this number -- roughly 25 percent of total Ph.D. requirements for medical research manpower -- can be drawn from these other fields of science?

The flow models, which have proved helpful in estimating the input into medical research of Ph.D.'s in the biosciences and psychology, are not suitable for estimating the attraction of medical research for Ph.D.'s from all other fields of science. This is because medical and health-related research constitutes but one of many areas of research endeavor and other activities open to Ph.D.'s in these other science fields. Nevertheless, a substantial number of Ph.D.'s from these other science fields are now engaged in medical research.

It seems reasonable to assume, in view of past trends, that this number will increase as a proportion of the total by 1970. The additional Ph.D.'s needed can be divided into two broad groupings: (1) the social, behavioral, and other non-physical sciences (excluding psychology but including doctoral trained manpower in public health, social work, nursing, hospital administration, and other health professions), and (2) the physical, mathematical, and engineering sciences.

Participation of the former group has been rising sharply as the scope of medical research has broadened to encompass social and behavioral aspects of health and disease. It is estimated, therefore, that by 1970, participation of sociologists, anthropologists, other social and behavioral scientists, and Ph.D.'s in the health professions will bring into medical research approximately 2,000 additional Ph.D.'s -- an average of 200 per year.

As indicated in table 28, this would call for an increment of 4,400 Ph.D. trained researchers from the physical, mathematical and engineering sciences.

Table 28

Distribution by Field of Additional Ph.D.'s Needed to Meet
Medical Research Manpower Requirements, 1961-1970

Field	Number	Percent
Total, all fields	25,000	100.0
Biosciences	14,300	57.2
Basic medical sciences	9,000	36.0
Other biomedical sciences	5,300	21.2
Social and behavioral sciences	6,300	25.2
Psychology	4,300	17.2
All other <u>1/</u>	2,000	8.0
Physical sciences, mathematics, and engineering.	4,400	17.6

1/ Includes sociology, anthropology, social work, public health, etc.

What is the possibility that the number needed will be available?

The average annual increment of 440 physical scientists (largely chemists and physicists), mathematicians, and engineers would represent only a small fraction of the total number of Ph.D.'s in these fields. Between 1950 and 1967, about 21,000 Ph.D.'s in chemistry and nearly 11,000 Ph.D.'s in physics have been or will be awarded by U. S. schools.^{1/} Assuming that roughly 15 percent of the Ph.D. chemists working in universities, industry, and Government engage in medical research, 1961-1970, this would represent a total of 3,150 -- an annual average of 315. This would leave an additional 125 Ph.D. scientists to be drawn annually from physics, mathematics, engineering and related fields.

Is it feasible to anticipate that nearly 450 physical scientists, mathematicians, and engineers will be attracted to medical research each year, 1961-1970?

In attempting to answer this question, it should be noted that exciting research opportunities plus purposeful efforts by NIH through research training to orient such groups to medical research have already stimulated substantial medical research involvement of leading chemists, physicists, mathematicians and, more recently, engineers. It seems reasonable to expect that the challenge to apply the concepts of the mathematical and physical sciences to the study of biological phenomena, coupled with intensified training efforts, undoubtedly will attract many more in the decade ahead. And the creative talents of physical scientists are

^{1/} See Appendix table 12 for actual output 1950-1960, and projections, 1961-1967.

especially needed to take advantage of the opportunities presented by the revolution in instrumentation and the potential for studying physiological and chemical processes under conditions that maximize control and minimize error of observation.

Taking these two considerations into account, meeting the additional requirements for Ph.D.'s from all science fields looks feasible. Much will depend, however, upon incentives for graduate study, Ph.D. output through 1967, and the attractiveness of medical research in competition with an ever-widening spectrum of research opportunities on land, under the sea, in the air, and in outer space.

H. Impact of Rising Participation of Ph.D.'s in Research Upon the Educational Process

At this point, the question may be raised as to whether this rising involvement of Ph.D.'s in medical research diverted faculty energies away from teaching. Has it diminished faculty contact with students? Has it affected staffing patterns and, if so, with what consequences, today and for the future? Has it had a fruitful or deleterious impact upon the quality of research training?

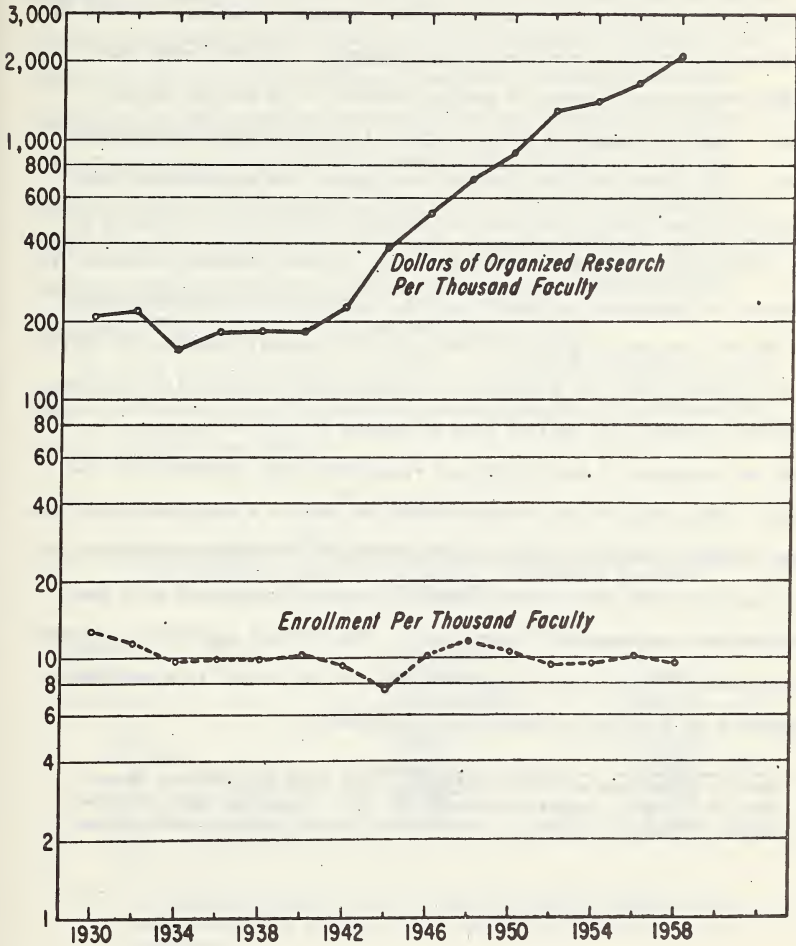
Obviously, each of these questions is of sufficient scope and significance to warrant full-scale studies. A number of such studies are currently underway. Nothing published to date pretends to deal with the totality of the Nation's medical research effort and the impact of this effort upon graduate education in the United States.^{1/}

^{1/} See, Berelson Bernard, Graduate Education in the United States; Kidd, Charles V., American Universities and Federal Research; American Assembly Federal Government and Universities; Rosenberg, Herbert H., "Research and the Financing of Higher Education," Higher Education, Oct.-Nov., 1961.

However, Chart 7 indicates that the crude ratio of 10 students per faculty member has remained constant while dollars of organized research per faculty member have risen ten-fold. While this comparison suggests the ability of faculty (here equated with Ph.D.'s) to participate in research without increasing the student/faculty ratio in the aggregate, studies in depth are needed to assess the impact of rising research participation upon the graduate educational process in individual institutions.

ENROLLMENT AND DOLLARS OF ORGANIZED RESEARCH PER THOUSAND FACULTY IN INSTITUTIONS OF HIGHER EDUCATION

Thousands



I. Assessment of Less than Doctoral
Manpower Requirements

The preceding analysis has concentrated upon doctoral-trained manpower. However, the supply of professional workers engaged in medical research is by no means limited to doctoral-trained manpower. In 1960, more than 10,000 professional workers in medical research -- 26 percent of the total -- had not completed formal academic training through the doctoral level. This group includes chemists, biologists, and psychologists who have established their competence as independent researchers, largely but not exclusively in industry and Government. It also includes scientists in a number of fields such as public health, social work, and nursing where the master's degree is generally recognized as terminal preparation. While it is estimated that the proportion of professional workers with less than doctoral training will decline from 26 percent in 1960 to 22 percent in 1970, an increment of some 8,500 such researchers will, nevertheless, be needed. This calls for an average of 850 per year -- a tiny fraction of the total output of master's degree in these fields.^{1/} Consequently, there can be no question that the required number of medical researchers with less than doctoral training will be available. The critical question is whether the caliber of their research training will be high enough to ensure their competence to function as independent researchers.

^{1/} Health, Education and Welfare Trends, 1961 edition, provides trend data on all M.A. degrees conferred (p. 42). Appendix table 13 shows master's degrees awarded in social work, public health, and nursing.

J. The Probable Balance

The foregoing analysis suggests that the potential supply will be available to meet the Nation's needs for 77,000 well-qualified scientists in medical research by 1970. The analysis, through (1) the use of flow models for the core groups of M.D.'s and Ph.D.'s in biosciences and psychology and (2) estimates of availability matched against research participation rates for the other groups with doctoral and less than doctoral training, also suggests that the net additional requirement of 45,000 scientists, 1961-1970, can be met, assuming continued and enlarged research training efforts and expanded support for research and the construction of health research and related facilities.

Table 29 presents a balance sheet -- a comparison between estimated additional manpower requirements and potential supply of scientists for medical research, 1961-1970.

Table 29

Comparison Between Estimated Additional Manpower Requirements
and Potential Supply of Scientists for Medical Research,
1961-1970

Level of training	Estimated additional requirements	Potential supply
Total	45,000	45,500
Doctoral	36,500	37,000
M.D., D.D.S., D.V.M.	11,500	12,000
Ph.D., Sc. D.	25,000	25,000
Less than doctoral (M.S., M.P.H., M.A., B.S., A.B.)	8,500	8,500

1/ See Appendix tables 6 - 10 for flow models showing year-by-year input for M.D.'s and Ph.D.'s in the biological sciences and psychology.

K. Some Qualifying Observations on the Estimate of M.D.'s and Ph.D.'s Entering Medical Research, 1961-1970.

The flow models used to analyze the potential supply of M.D.'s and Ph.D.'s in the biosciences and psychology illustrate that:

1. Nearly two-thirds of the new doctoral-level entrants into the medical research manpower pool, 1961-1970, will be drawn from scientists who received their M.D. or Ph.D. degrees prior to 1962, the remaining one-third will come from those completing their basic M.D. or Ph.D. training, 1962-1967;
2. New entrants flowing into the research manpower pool in any one year are drawn from those who have been trained from three to 15 years before;
3. The long-term payoff of today's fellowship and training programs shows up in the enlarged supply and sharpened skills of tomorrow's researchers.

Unfortunately, these models may also convey a misleading impression of an automatic or controlled flow of the desired numbers of researchers in quantities precisely sufficient to meet estimated needs. This, coupled with the fact that the analysis indicates that the potential supply may match future requirements, suggests that the problem of meeting the Nation's manpower needs for medical research has already been solved.

Consequently, some qualifying observations are warranted to:

- (1) put the conclusions in proper perspective and,
- (2) reemphasize the critical assumptions and their influence upon the analysis of the flow of manpower into medical research.

1. It has been assumed that nearly 20 percent of those currently engaged in medical research will need to be replaced by 1970. Death and retirement can be predicted with some degree of certainty but movement out of medical research into other activities necessarily represents a judgmental estimate. Consequently, if the actual movement of medical researchers into other activities exceeds the estimate (p.44), the additional number required by 1970 would increase correspondingly.
2. In estimating the input of doctoral-trained scientists into medical research, as shown in the flow models, it has been assumed that:
 - a. Research combined with teaching and/or service will become an increasingly attractive and productive career pattern for M.D.'s. The unstated premise implicit in this assumption is that opportunities for such careers will continue to expand through increased support for research and for research training essential to encourage and develop scientific capabilities of M.D.'s who seek careers in research and academic medicine;
 - b. The proportion of basic medical scientists engaged in research will continue at the prevailing 90 percent participation rate. Again, the implicit premise underlying this assumption is that research and research training opportunities will continue to expand and attract this core group of basic scientists.

- c. Research and research training opportunities will expand to attract larger numbers of scientists from the fields of the social and behavioral sciences and from the physical sciences, mathematics, and engineering.

Whether this assumption holds true will depend largely upon the exciting quality of opportunities available in medical research as compared with all other types of endeavor open to these Ph.D.'s from the physical and behavioral sciences.

3. Thus, it is clear that meeting medical research manpower requirements, 1965-1970, depends upon one fundamental assumption that support for research training, the conduct of research, and the construction of health research and related facilities will continue to expand, adapting whatever new mechanisms are best suited to the advancement of medical research in the national interest.

In short, there is nothing intrinsically "accurate" or "inaccurate" with respect to these assumptions. In each instance, however, it is believed that the assumptions constitute reasonable expectations, taking into account (1) experience, (2) prevailing trends, and (3) the outlook for the future.

VI. THE LONG-RANGE OUTLOOK FOR OUTPUT OF M.D.'S AND PH.D.'S.

As illustrated in the models described in the preceding section, researchers who will receive their M.D. or Ph.D. degrees this year, 1961-62, will begin to enter the medical research manpower pool around 1965. Some receiving their doctoral degrees, 1963-65, will enter into medical research by 1970; most of these M.D.'s and many of these Ph.D.'s, however, will enter after 1970. Moreover, it has been assumed that M.D.'s after 1965 will not enter the research manpower pool until after 1970; Ph.D.'s after 1967 will not enter until after 1970.

Nevertheless, both of these groups are crucial for the continued growth of medical research beyond 1970. The training of these groups will impose additional staffing requirements upon medical schools and graduate schools. When trained, however, these groups also represent potential faculty essential for (1) the predictable expansion of graduate schools as enrollment swells in 1966 and subsequent years and (2) staffing of the 20 new medical schools that America will need by 1975. 1/

A. The Resource Base for Future Growth, 1960-1970.

The resource base for the expansion of medical research manpower will broaden between 1960 and 1970. Five factors discussed below -- enlargement of the 20-24 age group, a sharp expansion in the population base from which new M.D.'s and Ph.D.'s must be drawn, rising college enrollment, rising graduate enrollment, and increased educational opportunities for talented youth -- will contribute to broaden the base substantially.

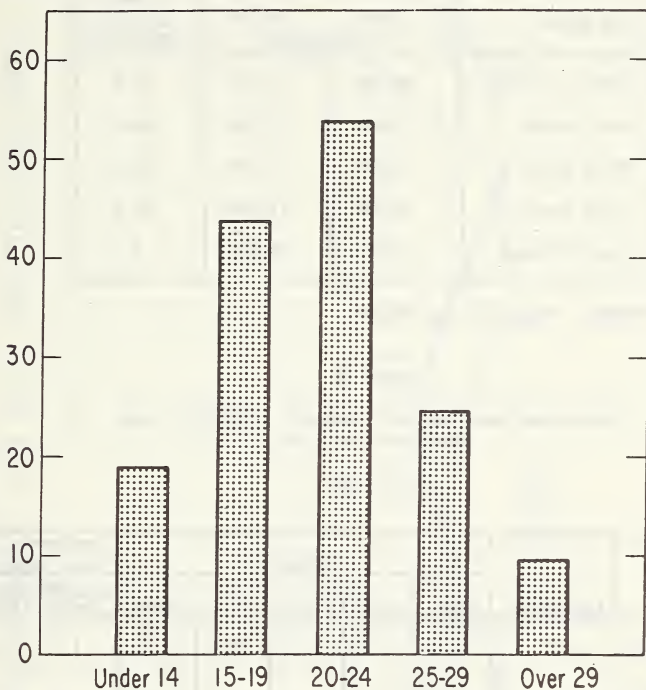
1/ Physicians for a Growing America. Report of the Surgeon General's Consultant Group on Medical Education. PHS Publication No. 709, 1959.

Population Base Will Expand

Between 1960 and 1970, the Nation's population in the 20-24 group will increase by more than 50 (53.3) percent (chart 8). This is by far the largest percentage increase for any of the key age groups shown on chart 8. The numbers in this age group will rise from 11.3 million to an estimated 17.3 million in 1970 (table 30). This is the age group from which expanded enrollments in graduate and medical schools will be drawn.

PERCENT CHANGE IN POPULATION AGE GROUPS 1960-1970

Percent
Increase



SOURCE : Bureau of the Census

RAS-OPP-NIH-12/61

Table 30

Increase in U.S. Population, by Age Groups, 1960-1970

Age group	1960 (thousands)	1970 (thousands)	Percent increase 1960-1970
Under 14 years	56,367	67,172	19.2
15-19 years	13,406	19,262	43.7
20-24 years	11,311	17,343	53.3
25-29 years	10,946	13,640	24.6
Over 29 years	88,096	96,363	9.4

SOURCE: Bureau of the Census.

Table 31

Population Base for Ph.D. Output, 1930-1960, and
Projection to 1970

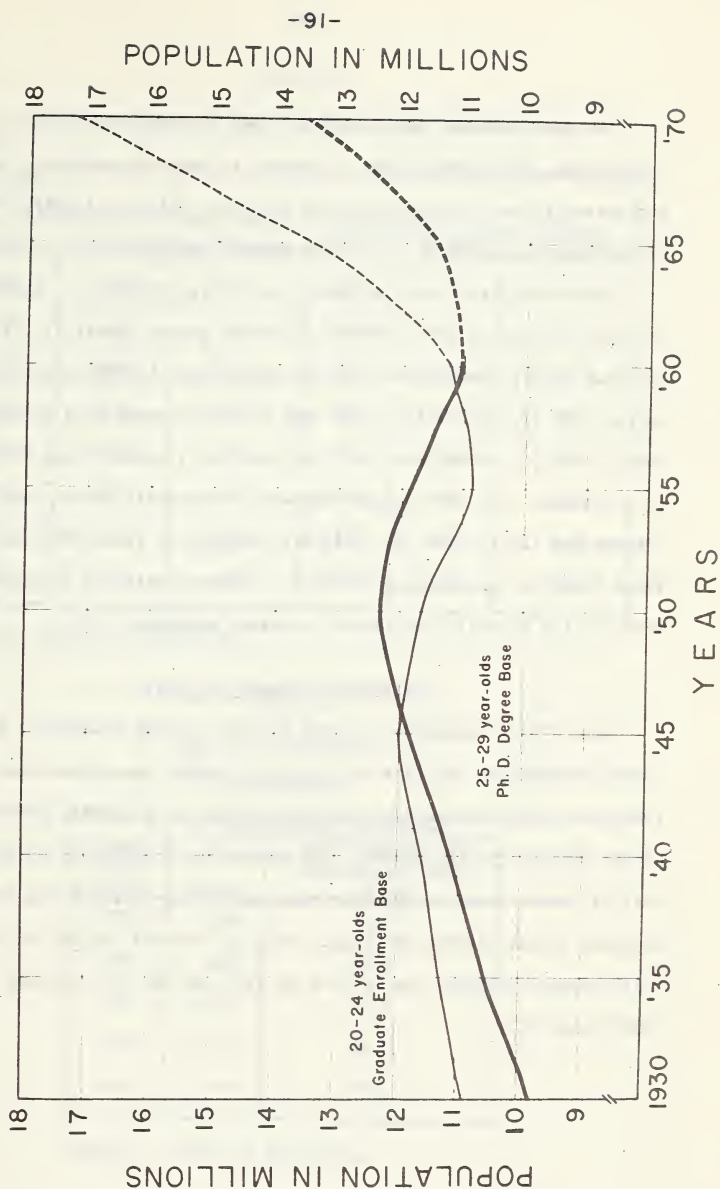
(millions)

Supply for:	Age group	Years					Increase 1970 over 1930-1960	
		1930	1940	1950	1960	1970	average	
							Number	Percent
College entrance	15-19	11.6	12.3	10.6	13.4	19.3	7.3	60.8
Graduate & professional training	20-24	10.9	11.6	11.6	11.3	17.3	5.9	51.8
New M.D.'s & Ph.D.'s	25-29	9.8	11.1	12.3	11.2	13.6	2.4	22.5

SOURCE: Bureau of the Census.

Chart 9

POPULATION BASE FOR Ph.D. OUTPUT, 1930-1970



SOURCE: Bureau of the Census

RAS - OPP-NIH-12/61

The next greatest increases will come from equally critical population groups, 15-19 and 25-29. In short, as shown in table 31, the population picture between 1960 and 1970 will shift radically, reflecting the coming of age of the postwar baby crop.

This shift also marks an abrupt break with the past in terms of absolute numbers in the 20-24 and 25-29 age groups (chart 9). For the past thirty years, these two age groups have hovered within the narrow band of 10-12 million; by 1970 the 20-24 group will be more than 17 million strong and the 25-29 group will contain more than 13.5 million. The 1970 Census estimates simply tell us how many persons age 12-21, alive in 1962, will survive to reach 20-29 in 1970. These facts are encouraging for those concerned with the resource base for the expansion of medical research manpower.

College Enrollment Will Rise

Since 1955, college enrollment has been rising steadily. This steady increase in the face of a nearly constant population base indicates rising aspirations and expectations as a growing proportion of the Nation's youth complete high school and continue on to college. This is demonstrated by the fact that nearly one-third of the pupils who were in the fifth grade eight years ago entered college in 1961. This compares with one out of four in 1953 and one out of seven in 1938 (table 32).

Table 32

Retention Rates of Fifth Graders to College Entrance

Year of entrance into 5th grade	entering 5th grade	High school graduates	First-time college student		
			Year	Number	Percent
1925	1000	316	1933	112	11.2
1930	1000	417	1938	148	14.8
1935	1000	439	1943	119	11.9
1940	1000	481	1948	NA	NA
1945	1000	524	1953	266	26.6
1950	1000	582	1958	308	30.8
1951	1000	593	1959	313	31.3
1952	1000	604	1960	319	31.9

SOURCE: Office of Education.

Table 33

High School Graduates

(in thousands)

School year ending	High School Graduates	
	Total	as a percent of persons 17 years of age
1920	311	16.8
1930	667	29.0
1940	1,221	50.8
1950	1,200	59.0
1958	1,506	64.8

SOURCE: Office of Education.

Enlargement of the college enrollment base is further indicated by the fact that nearly two-thirds (64.8 percent) of the 17-year-old cohort in 1958 were high-school graduates as compared with one-half in 1940, and one-sixth in 1920 (table 33).

This year, 1961-62, there are 3.9 million students enrolled in colleges and universities. This represents nearly a one-third (32 percent) increase since 1956 (table 34). More important, the 8 (7.8) percent jump over last year tells us that enrollment is expanding at an accelerated pace.

Table 34

College Enrollment, 1956-61
(Enrollment in thousands)

Year	Total enrollment	Percent increase since		
		1956	1958	1960
1956	2,947	-	-	-
1957	3,068	4.1	-	-
1958	3,259	10.6	-	-
1959	3,402	15.4	4.4	-
1960	3,610	22.5	10.8	-
1961	3,891	32.0	19.4	7.8

SOURCE: Office of Education, Opening (Fall) Enrollment In Higher Education.

For all practical purposes, the freshman class of 1961-62 sets the upper limit on those likely to enter the medical research manpower pool by 1970. The freshman class of 1961-62 will graduate in June 1965. Those who go on for graduate or professional training will not receive Ph.D. or M.D. degrees before June 1968 at the earliest; many will not complete their doctoral studies until after 1970. Even for those who receive doctoral degrees in 1968, postdoctoral training for Ph.D.'s and internship and residency for M.D.'s will defer their entrance into the medical research manpower pool until 1970 -- and beyond.

Graduate Enrollment in the Sciences Will Expand

If total college enrollment has been rising, what has been happening to graduate enrollment in the science fields of greatest relevance for medical research? Between 1954 and 1960, graduate enrollment in these selected science fields increased 36 percent. Graduate enrollment in the biosciences increased 24 percent over this period -- averaging 3.3 percent per year. However, between 1960 and 1961, graduate enrollment in the biosciences climbed steeply, rising more than 10 percent, or better than three times the average rate of increase for the preceding six-year period. As shown in table 35, enrollment in the basic medical sciences mounted even more sharply.

Table 35

Comparative Average Annual Percentage Increases in Graduate Enrollment in Selected Science Fields at 74 of 80 Leading Schools, 1953-54 to 1959-60 and 1959-60 to 1960-61

Field	Percentage increase in graduate enrollment	
	Average annual increase, 1953-54 to 1959-60	1959-60 to 1960-61
Total, selected science fields	5.2	10.8
Biosciences	3.3	10.3
Basic medical sciences	3.3	15.3
Other biosciences	3.3	6.5
Mathematics & statistics	15.6	20.0
Physical sciences	4.8	7.9
Psychology	4.5	15.9
Selected social sciences	3.0	10.2
Social work	4.2	5.3

SOURCE: National Institutes of Health,
Resources Analysis Memo No. 3, June 1961.

These are encouraging developments, especially when two-thirds of those in graduate training in the biological, physical, and psychological sciences are enrolled in Ph.D. programs (table 36).

Table 36

Intermediate-Level Graduate Enrollment in Selected Science Fields at 80 Leading Schools, 1960-1961

Field	Number of intermediate-level graduate students			Doctoral enrollment as percent of total
	Total ^{1/}	Enrolled for doctorate	Enrolled for Master's	
Total, Selected science fields	18,932	11,374	7,558	60
Biosciences	4,034	2,759	1,275	68
Basic medical sciences	1,946	1,323	623	68
Other biosciences	2,088	1,436	652	69
Mathematics and Statistics	2,467	1,260	1,207	51
Physical sciences	7,035	4,754	2,281	68
Psychology	2,571	1,762	809	69
Selected social sciences	1,248	709	539	57
Social work	1,577	130	1,447	8

SOURCE: National Institutes of Health, Resources Analysis Memo No. 3, June 1961.

^{1/} Excludes approximately 5,000 students at the intermediate level for whom 8 universities did not report a breakdown by degree category. These 8 institutions account for 18 percent of intermediate-level enrollment and grant about 21 percent of the Ph.D. degrees in the selected science fields.

These trends in graduate enrollment are further illuminated by two recent studies of the intentions and follow-through of college seniors with respect to graduate and professional study. The 1958 college senior class was followed-up two years later to ascertain where the group was. More than one-third of the 1958 college seniors were in graduate school in 1960 -- two years later. This proportion, while high, understates graduate study for those who majored in the biosciences. About 60 percent of this group and about 75 percent of the men who majored in the biosciences as undergraduates were enrolled in graduate school.

This rising propensity for graduate training is confirmed by a nationwide survey of the June 1961 senior class which shows that one-third of this group intended to enroll for graduate or professional study in the fall of 1961. ^{1/} About 20 percent had already been accepted by the school of their choice. Again, roughly 60 percent of the bioscience majors and three-fourths of the men in this field were going on for graduate study.

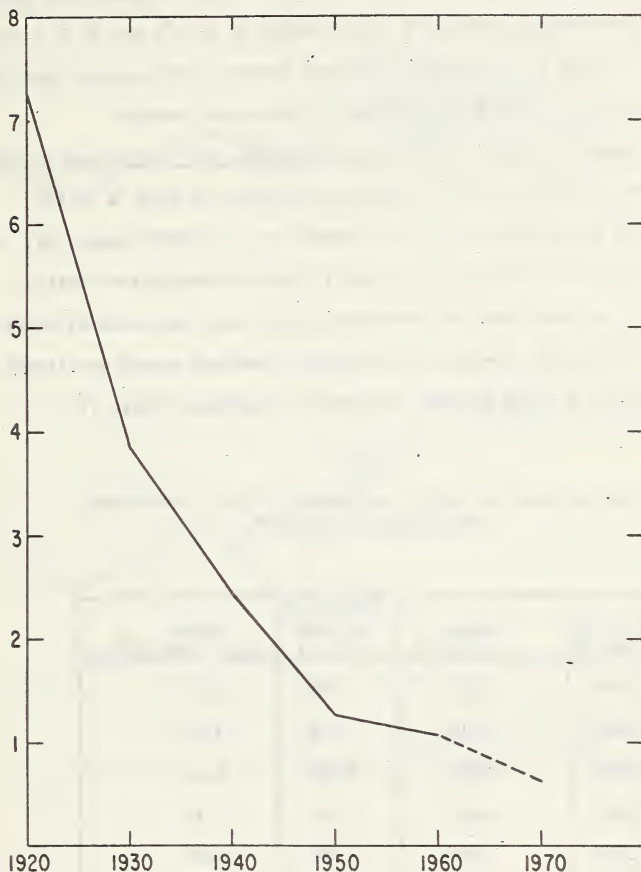
What about the quality of the 1961 college seniors majoring in biology? Of those in the top fifth of their class, 95 percent were going on for graduate study. Also continuing on for graduate study were 80 percent of the above average students, and about 50 of those who graduated in the bottom half of their classes. ^{2/} Thus quality as measured by prior academic performance ranges the spectrum from the top to the less talented. However, the input of nine-tenths of top group and 80 percent of the above average group augurs well for the quality of the future supply of Ph.D.'s four to six years hence.

^{1/} Great Aspirations, A Preliminary Report by the National Opinion Research Center of the University of Chicago of a study cosponsored by the National Institutes of Health, the National Science Foundation, and the Office of Education.

^{2/} Special tabulation prepared by the National Opinion Research Center, based upon 1961 College Senior Survey.

RATIO OF OUTPUT OF M.D.'S TO SCIENCE Ph.D.'S 1920 - 1960, PROJECTED TO 1970

Ratio of M.D.
to Ph.D.



SOURCES: M.D.'s 1920-1960 - JAMA 178: 647 (table 14), 1961;
1970 - Physicians for a Growing America, P. H. S
pub. 709, p. 3 (table 2), 1959.

Ph.D.'s - Investing in Scientific Progress, NSF
Report 61-27, p. 13, 1961.

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In short, considerable enlargement of the population base, a marked expansion in college and graduate enrollment, and increased educational and research opportunities for talented youth -- will substantially broaden the base from which the Nation's future supply of M.D.'s and Ph.D.'s will be drawn. Taking these and other relevant factors into account, what is the outlook for output of M.D.'s and Ph.D.'s during this decade?

B. Output of M.D.'s and Ph.D.'s, 1946-1960, and Projections to 1970.

Since 1920, the ratio of the output of M.D.'s to Ph.D.'s in the sciences has declined from 7 to 1 to about 1 to 1 in 1960 (chart 10). It is likely that this long-term trend will continue through the Sixties (table 37). A comparison of enrollment trends since the close of World War II shows the relatively slow rate of increase in medical school enrollment as contrasted with a sharp upsurge in graduate enrollment (chart 11).

Table 37

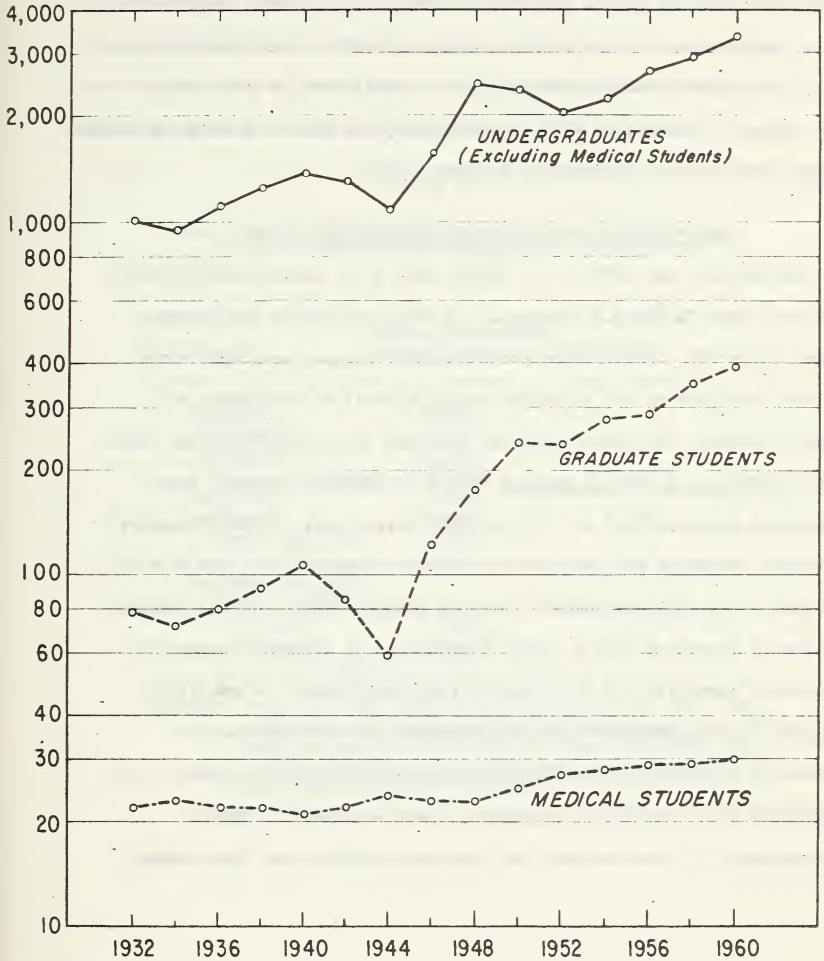
Ratio of Output of M.D.'s to Science Ph.D.'s, 1920-1960,
and Projection to 1970

Year of degree	Output of M.D.'s	Output of science Ph.D.'s	Ratio M.D.'s/Ph.D.'s
1920	2,680	368	7.28
1930	4,735	1,222	3.87
1940	5,097	2,065	2.47
1950	5,553	4,326	1.28
1960	7,081	6,515	1.09
1970	8,000	13,000	.62

SOURCE: M.D.'s, 1920-1960 - JAMA: Vol. 178 (Nov. 11, 1961) p. 647 (table 14);
1970 projection - Physicians for a Growing America, Public Health Service Publication No. 709, p. 3, 1959;
Ph.D.'s, 1920-1970 - Investing in Scientific Progress, National Science Foundation (NSF 61-27), p. 13, 1961.

ENROLLMENT IN INSTITUTIONS OF HIGHER EDUCATION

Thousands of Persons



SOURCES : Office of Education and American Medical Association

Thus, it appears that two diametrically opposite considerations will govern the output of M.D.'s and Ph.D.'s during this decade. M.D. output is, in large measure, fixed by the spaces available in existing schools and the new spaces made available by the establishment of new schools. Ph.D. output, in contrast, will be governed by the number of well-qualified students desiring and undertaking graduate study.

M.D. Output, 1946-1960, and Projections to 1970

Between 1961 and 1970, it is likely that U. S. medical schools will award more than 75,000 M.D. degrees -- 8,000 more than in the previous decade (table 38). This estimate of cumulative output over the decade has been developed by the Resources Analysis Staff of the Office of Program Planning, NIH, based upon the 1965 and 1970 projections set forth in Physicians for a Growing America (the Bane Report). Because these projections were confined to 1965 and 1970 output only, it was necessary to develop estimates for each year in order to simulate the flow of M.D.'s from each class into the medical research manpower pool. Output through 1965 can be estimated with a fairly high degree of accuracy inasmuch as it reflects completion of training for the four classes now enrolled, 1961-1962. It is possible that the estimates for 1966-1970 may be exceeded if (1) existing schools act promptly to expand enrollment (especially those where such commitments have been made to State legislatures), (2) new two-year and four-year schools that have already

announced their program plans or received legislative authorization (Brown, Rutgers, Connecticut, New Mexico, Arizona, Texas, and California) proceed rapidly with organization, construction of necessary teaching, clinical, and research facilities, and (3) Federal programs stimulate, accelerate, and provide the necessary impetus for such action.

Table 38

Output and Projections of U.S. Medical School Graduates
by Five-Year Periods.

Years	Output, 1946-1960 and projections, 1961-1970
1946-1950	28,405
1951-1955	32,721
1956-1960	34,443
Total 1951-1960	67,164
1961-1965	36,219
1965-1970	39,000
Total 1961-1970	75,219
Increase 1961-1970 over 1951-1960	
Number	8,055
Percent	12.0 %

SOURCE: Data for 1946-1960 - JAMA 178:646 (table 14), 1961. Projections - Physicians for a Growing America, PHS Publication No. 709 (1959) for the years 1965 and 1970. Projections for other years interpolated by National Institutes of Health.

However, the supply of new M.D.'s is not limited to the output of U. S. schools.^{1/} Since 1950, the number of newly licensed physicians who received their degrees from foreign institutions has been rising. It should be noted, of course, that about one-fourth of this total represents U. S. citizens who have received their medical education abroad. In 1960, this group of U. S. citizens trained in foreign medical schools was equivalent to the output of three U. S. schools.^{2/} If the 1950-1960 trend continues, the number of newly licensed foreign-trained physicians would approximate two-thirds of the output of U. S. schools by 1970. This possibility cannot be totally rejected despite the recent measures that have been taken to diminish this influx through national examination requirements and tighter exchange controls. It seems more probable, however, to assume the proportion of newly-licensed, foreign-trained physicians may approximate 20 percent of the annual supply of new M.D.'s. This possibility suggests that the total addition to the U. S. supply of M.D.'s 1961-1970, from both domestic and foreign sources, might approximate 94,000, with an average annual increment of 9,400.^{3/}

Ph.D. Output, 1946-1960
and Projections to 1970

The National Science Foundation has estimated that Ph.D. output in the sciences will reach 13,000 in 1970, roughly double the number awarded in 1960.^{4/} The outlook is favorable that this projection may be achieved,

^{1/} See Appendix table 14.

^{2/} See Appendix table 15.

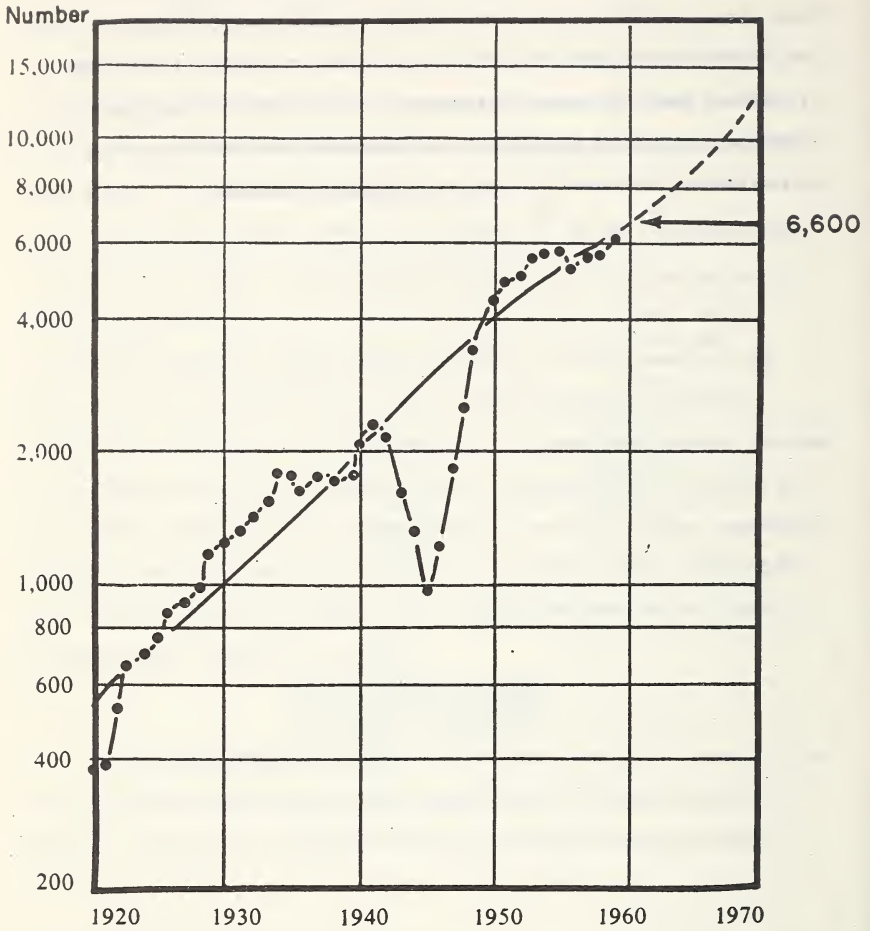
^{3/} See Appendix table 16.

^{4/} Investing in Scientific Progress, National Science Foundation Report, NSF 61-27.

and perhaps surpassed, taking into account long-term trends in Ph.D. output in the sciences (chart 12), substantial broadening of the population base from which Ph.D.'s are drawn, the rising propensity of American youth for graduate training, the major advances that have taken place in science education in secondary schools, and the growing attractiveness of careers in research and higher education.



NUMBER OF SCIENCE DOCTORATES
GRANTED DURING YEAR



SOURCE: National Science Foundation

RAS-OPP-NIH-1/62

In its report, "Investing in Scientific Progress", the National Science Foundation has taken note of these factors and has identified the 1970 projection of 13,000 Ph.D.'s in the sciences as a conservative one. Independent estimates developed by the National Institutes of Health suggest that the total output of Ph.D.'s in the sciences may exceed 14,000 by 1970. While this possibility exists, the official estimate of 13,000 Ph.D.'s in the sciences has been accepted as the point of departure for the following discussion of total Ph.D. output during the decade.

In order to estimate the potential future supply of Ph.D.-trained scientists in fields and disciplines most directly relevant to medical research, the National Institutes of Health needed to (1) develop more detailed year-by-year Ph.D. output projections for the biosciences and psychology for use in the flow models described in the foregoing section and (2) interpolate year-by-year output in line with the 13,000 projection for 1970, in order to estimate the probable number of scientists, in fields other than the biosciences and psychology, who might receive Ph.D.'s, 1961-1967, and hence, might be drawn into medical research by 1970.

The detailed year-by-year projections for the biosciences were developed individually for each discipline, taking into account the long-term trend in each discipline's output as a proportion of total Ph.D. output. Annual totals for the disciplines were then cumulated to derive the field total for the biosciences. While the margin of error usually

increases as projections are refined into detailed discipline-by-discipline estimates, past experience suggests that radical shifts are unlikely or can be anticipated, in large part, by a careful examination of long-term trends and prevailing forces.^{1/} It is estimated that total Ph.D. output in the sciences over the ten-year span, 1961-1970, will range between 90,000 to 95,000. As indicated in table 39, it is estimated that 1961-1970 output will exceed the prior decade by more than 40,000 Ph.D.'s in the sciences. Moreover, it appears that output during the second half of the Sixties may approximate 56,000 Ph.D.'s in the sciences -- roughly a 40 percent increase over the 1961-1965 period.

These aggregate estimates have been broken down in greater detail in order to forecast the probable output in the biosciences and psychology -- fields that provide the major share of Ph.D. trained scientists for medical research. It is estimated that more than 21,500 young men and women will receive their Ph.D.'s in the biosciences and nearly 12,500 in psychology, 1961-1970 (table 40). Within the biosciences, it is estimated that about 12,000 Ph.D.'s will be awarded in the basic medical sciences and over 9,400 in the other biological sciences. This means that nearly 10,000 more Ph.D.'s will be awarded in the biosciences in the Sixties as compared with previous decade, 1951-1960.

^{1/} See Appendix tables 17 and 18 for full notes on methodology.

Table 39

Ph.D.'s Awarded in the Sciences, 1946-1960,
and Estimated Output, 1961-1970

Year	Estimated number of Ph.D.'s awarded	Percentage distribution
1946-1950	13,450	-
Total 1951-1960	<u>56,250</u>	<u>100.0</u>
1951-1955	<u>26,925</u>	<u>47.9</u>
1956-1960	29,325	52.1
Estimated output		
1961-1970	<u>96,300</u>	<u>100.0</u>
1961-1965	<u>40,100</u>	<u>41.6</u>
1966-1970	56,200	58.4
Increase 1961-1970 over 1951-1960	40,050	-

SOURCES: 1946-1960 - National Research Council;
1961-1970 projection - National Institutes of Health
using National Science Foundation projection of
13,000 in 1970 as the terminal point. Investing in
Scientific Progress, NSF 61-27, 1961.

Table 40

Output of Ph.D.'s in Biosciences and Psychology, 1951-1960, and
Projection, 1961-1970

Field	Output 1951-1960	Projection 1961-1970	Increase 1961-1970/1951-1960	
			Number	Percent
All biosciences	<u>11,838</u>	<u>21,538</u>	<u>9,700</u>	<u>81.9</u>
Basic medical sciences	<u>6,472</u>	<u>12,120</u>	<u>5,648</u>	<u>87.3</u>
Anatomy	348	582	234	67.2
Biochemistry	2,411	4,604	2,193	90.9
Biophysics	218	648	430	197.2
Microbiology	1,713	3,054	1,341	78.3
Pathology	121	239	118	97.5
Pharmacology	493	788	295	59.8
Physiology	1,168	2,205	1,037	88.8
Other biosciences	<u>5,366</u>	<u>9,418</u>	<u>4,052</u>	<u>75.5</u>
Botany	1,229	1,779	550	44.8
Entomology	755	1,425	670	88.7
Genetics	525	1,624	1,099	209.3
Plant pathology	538	1,169	631	117.3
Zoology	2,054	2,579	525	25.6
Other	265	842	577	217.7
Psychology	6,819	12,445	5,626	82.5

SOURCE: National Institutes of Health. These projections take account of Ph.D. output trends 1950-1960, based upon National Research Council Doctorate Production in United States Universities 1936-1956, publication 582, pp. 6-7; 1957-60 unpublished data supplied by the National Research Council.

Separate projections have also been developed on a year-by-year basis for each of the individual disciplines shown in table 40, taking into account trends in output, 1946-1960, trends in graduate enrollment, 1954-1961, and factors which are likely to influence output in disciplines such as biophysics and genetics. (The detail showing year-by-year estimates and full notes on sources and methodology is contained in Appendix table 18).

In short, these projections of Ph.D. output, 1961-1970, if realized, bode well for the supply of medical researchers in 1970 as long as present efforts to encourage careers in science are maintained and expanded.

Summary

The long-range outlook for output of M.D.'s and Ph.D.'s looks promising when one takes into account:

1. The sharp expansion in the population age groups from which new M.D.'s and Ph.D.'s must be drawn (chart 9, p. 91);
2. Steeply rising enrollment at all levels of higher education which should substantially enlarge enrollments in graduate education, especially during the late Sixties and thereafter;
3. The growing propensity for American youth toward careers demanding graduate and professional training.

Taking into account these factors and long-term trends, it is estimated that U. S. schools will award about 75,000 M.D. and between 90,000-95,000 Ph.D. degrees in the sciences, 1961-1970. The attainment of these projections, however, depends heavily upon the continuing stimulus of effectively designed and operated training programs.

VII. IMPLICATIONS FOR NATIONAL POLICY.

The Congress, the Executive Branch, and the American people have increasingly recognized the urgent necessity for vigorous action to develop the scientific and professional manpower resources for the future. Only a few weeks ago, President Kennedy expressed his concern that:

"... one of the most critical problems facing this Nation is the inadequacy of the supply of scientific and technical manpower to satisfy the expanding requirements of this Nation's research and development efforts in the near future." 1/

In his newsconference, the President also called for a report on the specific measures that can be taken to develop necessary and well-qualified scientists to meet society's growing and complex needs.

It is not within the scope of this analysis to spell out the specific measures required to meet the Nation's needs for medical research manpower. It is, however, pertinent to summarize the national policy considerations that emerge from this report on manpower for medical research which has been prepared in response to the Committee's farsighted request.

1. Meeting the Nation's medical research manpower needs, 1965-1970, will require a continuing, substantial enlargement both of research facilities and of teaching facilities for medical and graduate education, including postdoctoral training.

2. Rising participation of M.D.'s in research and teaching careers will necessitate (1) increased emphasis upon research in undergraduate medical education, (2) expanded postdoctoral training opportunities for M.D.'s, and (3) more stable and challenging career opportunities in research and academic medicine, working in more adequate facilities with improvement needed in financial remuneration.

1/ New York Times, January 16, 1962, p. 14. Transcript of the President's News Conference, January 15, 1962.

3. Meeting manpower requirements for medical research will necessitate a steadily growing involvement of well-qualified Ph.D.'s in the sciences. This calls for (1) expansion in graduate enrollment, (2) doubling Ph.D. output, 1961-1970, and (3) enlarging the scope and enhancing the attraction of careers in medical and health-related research.

To achieve these objectives, it is essential to:

(1) Provide more general support for the graduate education process (including medical education and post-doctoral training). This investment in academic strength takes place at the point of maximum leverage in the sense that the faculty transmits knowledge, instills competence, and evokes the spirit of inquiry that must provide the essential foundation for research training. A strengthened university department not only gives better research training today, but will also be better prepared to take larger numbers of graduate and professional students in the future and to give them better training than it would otherwise be able to do.

(2) Reduce the attrition and accelerate the flow of graduate students toward the Ph.D. degree. At the present time, ten graduate students receive training for each Ph.D. awarded. It is true, of course, that a substantial proportion of those entering graduate training may not be seeking the Ph.D. Nevertheless, this extraordinarily high attrition rate reflects a serious wastage of talented manpower. The numbers of Ph.D.'s awarded each year could be expanded substantially if graduate students were enabled to carry out their Ph.D. course of study without unnecessary interruptions or diversions that unduly prolong the qualified student's completion of formal academic training.

4. Specialized and intensified research training at the post-doctoral level has become virtually an essential prerequisite for full-fledged entrance into medical research. At the present time, the bulk of this postdoctoral training takes place in educational institutions and imposes a heavy burden upon faculty time. The need to ameliorate this additional training load upon medical schools and graduate departments will become increasingly urgent as these schools attempt to accommodate the rising tide of graduate students and medical students. One possibility that warrants serious consideration is

enlargement of the Nation's postdoctoral training base to encompass first-rate research organizations where the Ph.D. may receive the benefits of advanced research training without impairing the capability of an educational institution to provide for its graduate and professional students.

5. Attainment of a \$3 billion medical research effort will call for a substantial expansion of the supply of highly skilled, professional-level technicians and subprofessional supporting personnel demanded to assist in increasingly complex, highly instrumented medical research activities. This, in turn, will require a deliberate effort to (1) identify these requirements more precisely both qualitatively and quantitatively, and (2) mount training programs specifically designed to expand supply and upgrade quality.

APPENDIX A

GROWTH IN THE NATION'S EXPENDITURES FOR MEDICAL RESEARCH
AND THE OUTLOOK FOR THE FUTURE

APPENDIX A

GROWTH IN THE NATION'S EXPENDITURES FOR MEDICAL RESEARCH
AND THE OUTLOOK FOR THE FUTURE

During the past decade, the Nation's health, prosperity, and national security have been greatly influenced by the growth of science and research. While the Nation's expenditures for research by no means portray the true significance of science in modern life, such a measure does provide a frame of reference for viewing the growth of medical research as a vital component of the national effort.

A. Growth of the Nation's Expenditures for Research and Development, 1930-1961.

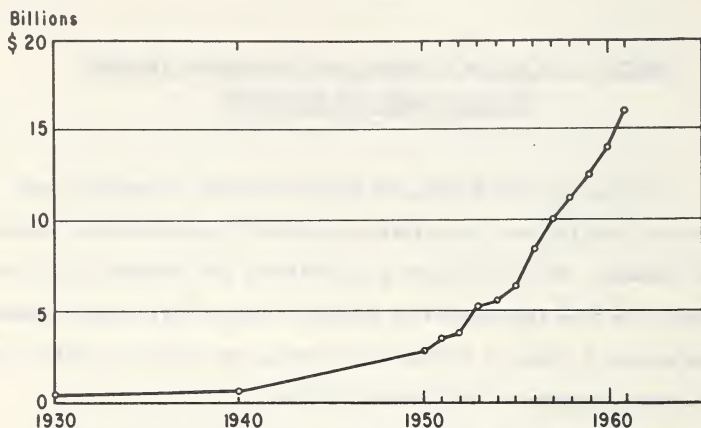
The significant trends in the magnitude and composition of the Nation's total expenditures for research and development for all purposes are summarized below.

1. Since 1940 the Nation's expenditures for research and development have mounted almost fifty-fold. This growth has been particularly rapid between 1950 and 1961. Expenditures climbed from \$2.9 billion to \$16 billion (chart 1).

2. Research expenditures have increased at a more rapid rate than gross national product, rising from .34 percent of GNP in 1940 to 3.08 percent in 1961 (chart 2).

Chart 1

TRENDS IN TOTAL NATIONAL EXPENDITURES
FOR PERFORMANCE OF RESEARCH AND DEVELOPMENT



SOURCES: 1930, 1940, The President's Scientific Research Board; 1950-52, Department of Defense; 1953-60, National Science Foundation; 1961, National Institutes of Health.

Chart 2

RELATION OF TOTAL NATIONAL EXPENDITURES
FOR RESEARCH AND DEVELOPMENT
TO GROSS NATIONAL PRODUCT

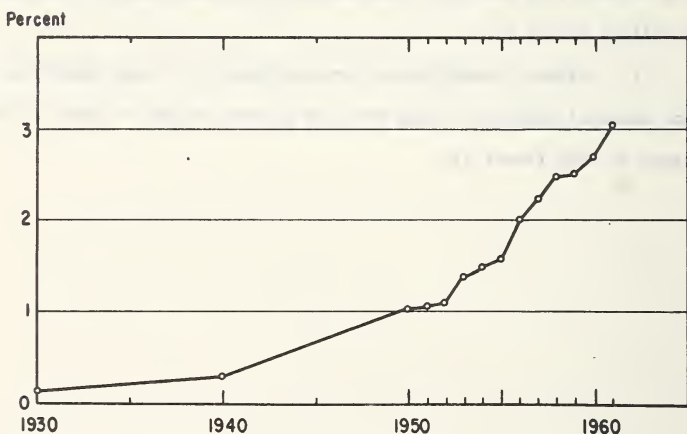


Table 1

Trends in Gross National Product and National Expenditures
For Performance of Research and Development, 1930-1961

	Gross National Product	National Research and Development	Research and Development as Percent of GNP
	(millions)		(percent)
1930	\$ 91,000	\$ 166	0.18
1940	100,600	345	0.34
1950	284,600	2,900	1.02
1951	329,000	3,400	1.03
1952	347,000	3,800	1.10
1953	365,000	5,150	1.41
1954	363,100	5,620	1.55
1955	397,500	6,390	1.61
1956	419,200	8,460	2.02
1957	442,800	10,040	2.27
1958	444,500	11,160	2.51
1959	482,800	12,430	2.57
1960	504,400	14,000	2.78
1961	520,000	16,000	3.08

Sources: Gross national product - Department of Commerce; National research and development expenditures--1930, 1940 The President's Scientific Research Board; 1950-1952 Department of Defense; 1953-1960 National Science Foundation; 1961 National Institutes of Health

3. Federal research expenditures, as reported by the National Science Foundation, increased roughly one billion dollars between 1940 and 1950--from \$74 million to \$1.1 billion. During the Fifties, however, the Federal outlay rose nearly seven-fold reaching \$7.7 billion in 1960 and jumping to \$8.8 billion in 1961 (chart 3). The increase in one year, 1960 to 1961, exceeded the increase of the entire decade 1940-1950.

4. Triggered by rising military research expenditures for national security and, more recently, by the Nation's space research activities, research and development costs have mounted from less than one percent of the Federal budget in 1940 to almost 3 percent in 1950 and to nearly 11 percent in 1961 (chart 4).

Table 2

Trends in Federal Expenditures for Research and Development and Federal Budgetary Expenditures, 1940-1961

Year	Federal budgetary expenditures	Federal research and development expenditures	Federal research and development as percent of budgetary expenditures
	(millions of dollars)		(percent)
1940	\$9,062	\$ 74	0.82
1945	98,416	1,591	1.62
1950	39,544	1,083	2.74
1955	64,389	3,884	6.03
1960	76,539	7,738	10.11
1961	81,503	8,789	10.78

Note: Research expenditures include outlays for facilities, but not for research training.

SOURCES: Bureau of the Budget and National Science Foundation

Chart 3
TRENDS IN FEDERAL EXPENDITURES
FOR RESEARCH AND DEVELOPMENT

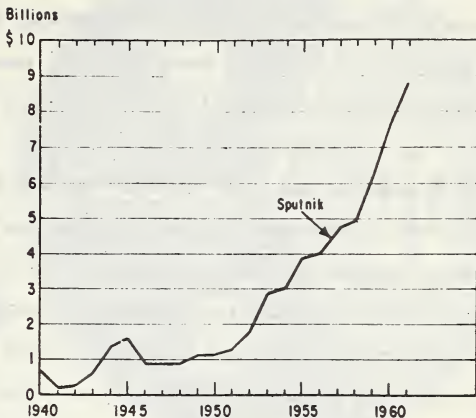
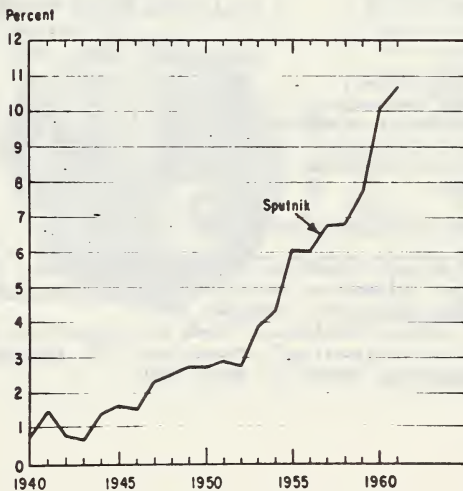


Chart 4
RELATION OF FEDERAL RESEARCH
AND DEVELOPMENT EXPENDITURES
TO TOTAL BUDGET EXPENDITURES



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5. Increased Federal funds for research have led to sweeping changes in the Nation's research economy. In 1960, the Federal Government supported almost three-fifths of all research conducted in the laboratories of American industry ^{1/} and in 1958 well over 70 percent of all separately budgeted research in universities. ^{2/}

6. The expansion of grant-type research programs of other Federal agencies has greatly diminished the scientific community's dependence upon the Department of Defense for continuing support. For example, in 1952 the Department of Defense financed approximately 70 percent of the Federal funds for project-type research of universities; in 1961, each of four agencies provided 10 percent or more, with one-third of the total coming from the National Institutes of Health (chart 5). These trends clearly reflect that the agency base of Federal support for research in universities has greatly broadened and become more diversified.

Table 3
Federal Support of Organized Research in Colleges and Universities,
by Agency, 1952-1961

	1952	1954	1956	1958	1960	1961
	(in millions)					
Total amount	\$ 151.2	\$140.9	\$171.8	\$282.3	\$464.1	\$ 489.4
	Percent distribution					
Total	100	100	100	100	100	100
Department of Defense	70	57	48	42	35	31
Atomic Energy Commission	9	12	11	11	9	10
National Institutes of Health	9	17	17	26	32	32
Department of Agriculture	9	10	15	11	7	7
National Science Foundation	1	3	6	7	13	14
Other agencies	2	1	3	3	4	6

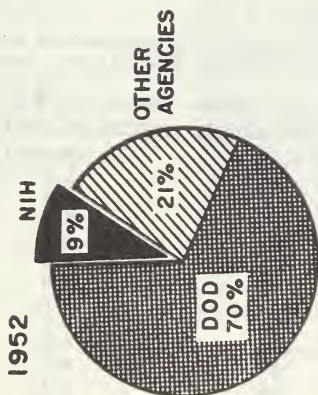
Source: National Science Foundation

^{1/} National Science Foundation, "Funds for Performance of Research and Development in American Industry", 1960, Reviews of Data on Research and Development, Number 30, September 1961.

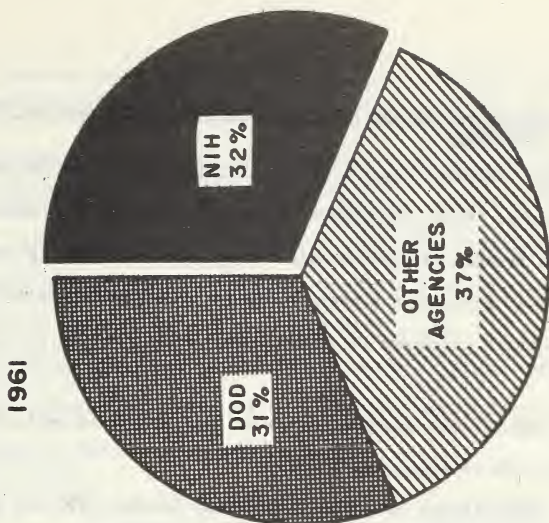
^{2/} National Science Foundation, "Funds for Research and Development in Colleges and Universities", Fiscal Year 1958, Reviews of Data on Research and Development, Number 19, April 1960.

Chart 5

NIH NOW SUPPORTS 1/3 OF FEDERALLY FINANCED RESEARCH IN UNIVERSITIES



\$ 151 MILLION



\$ 489 MILLION

AGENCY	1952	1961	GROWTH RATIO
	Millions	Millions	
TOTAL	\$151	\$489	3.2
NIH	14	157	11.2
Dept. of Defense	106	154	1.5
Other Federal Agencies	31	178	5.7

SOURCE: National Science Foundation

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B. The Growth of the Nation's Expenditures for Medical Research, 1940-1961.

Medical Research comprises a vital component of the Nation's total research effort. Thus, the growth of medical research has closely followed the broader pattern in many but not all respects. In recent years the growth also reflects a number of changes in organization and substance of research which influence the future needs and character of research manpower.

The significant characteristics of this growth in medical research expenditures can be summarized briefly:

1. Expenditures rose nearly five-fold between 1950 and 1960 (from \$148 million to \$715 million). Between 1960 and 1961, these expenditures increased by \$175 million, rising to 5.6 percent of total research and development expenditures (table 4).

Table 4

Medical Research and Development Expenditures and Relation to
Total Research and Development Expenditures, 1950-1961

	<u>Total research and development</u>	<u>Medical research and development</u>	<u>Medical R & D as percent of total R & D</u>
	(millions of dollars)		(percent)
1950	\$2,900	\$ 148	5.1
1951	3,400	163	4.8
1952	3,800	173	4.6
1953	5,750	203	3.9
1954	5,620	225	4.0
1955	6,390	240	3.8
1956	8,460	285	3.4
1957	10,040	397	4.0
1958	11,160	490	4.4
1959	12,430	587	4.7
1960	14,000	715	5.1
1961	16,000	890	5.6

SOURCES: Total research and development expenditures - Department of Defense and National Science Foundation; medical research expenditures - National Institutes of Health.

2. Medical research expenditures, until recently, have grown roughly in proportion to total expenditures for research and development. Since 1956, however, the medical research proportion has been rising steadily from 3.4 percent to 5.6 percent of total research--a 65 percent increase.

3. Federal support has become an increasingly significant component of the Nation's total medical research expenditures rising steadily from 32 percent in 1947 to 56 percent in 1961 (chart 6).

4. Undeterred by the increase in the Federal share, industry and other nonFederal sources of support have steadily and substantially expanded their outlays for medical research.

Table 5
NonFederal Support of Medical Research
1947 - 1961

(in millions)

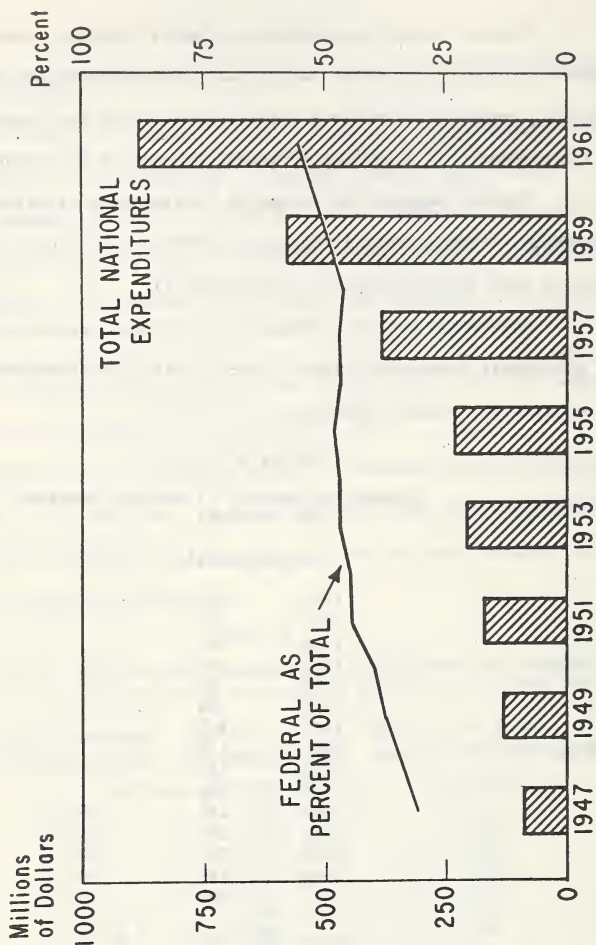
1947	\$60
1948	74
1949	82
1950	88
1951	90
1952	94
1953	107
1954	118
1955	122
1956	150
1957	211
1958	264
1959	297
1960	338
1961	394

Ratio 1961/1947 6.6

SOURCE: National Institutes of Health

Chart 6

TOTAL NATIONAL EXPENDITURES FOR MEDICAL AND HEALTH-RELATED RESEARCH, AND FEDERAL EXPENDITURES AS PERCENT OF TOTAL



SOURCE: National Institutes of Health

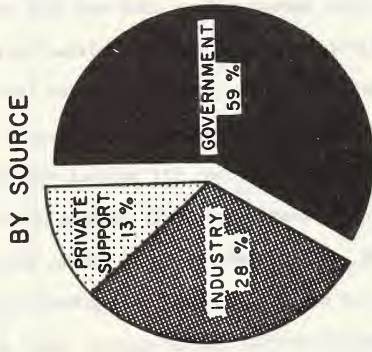
5. More than half of the Nation's medical research is conducted in the medical schools, universities, hospitals, and nonprofit research institutes throughout the United States. Close to thirty percent of the total is carried out in the laboratories of American industry. The remainder--less than 20 percent of the total--is performed in Federal and State government laboratories and hospitals. (chart 7).

6. As the scope of medical research has broadened, competent scientists with diverse backgrounds working in a wide variety of research environments have become increasingly involved in medical and health-related research. This development is reflected in the long-term shift in the proportion of NIH research grant funds awarded to scientists in medical schools as compared with those located in all other research environments (chart 8). The scissors-like change between 1960 and 1961 reflects substantial awards for clinical research centers, virtually all of which were established in medical schools in the first year of this new program.

In short, the growth of medical research expenditures followed the pattern for total R&D expenditures in that (1) medical research expenditures increased significantly in the past decade, (2) medical research expanded at a more rapid rate than GNP, and (3) Federal funds became increasingly important for the support of medical research. The growth of medical research has deviated from the over-all pattern in at least two critical characteristics: (1) unlike the over-all pattern, nonFederal expenditures

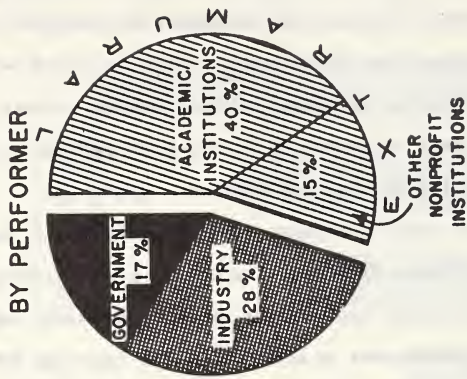
Chart 7

NATIONAL EXPENDITURES FOR MEDICAL AND HEALTH RELATED RESEARCH 1961



\$ 890 MILLION

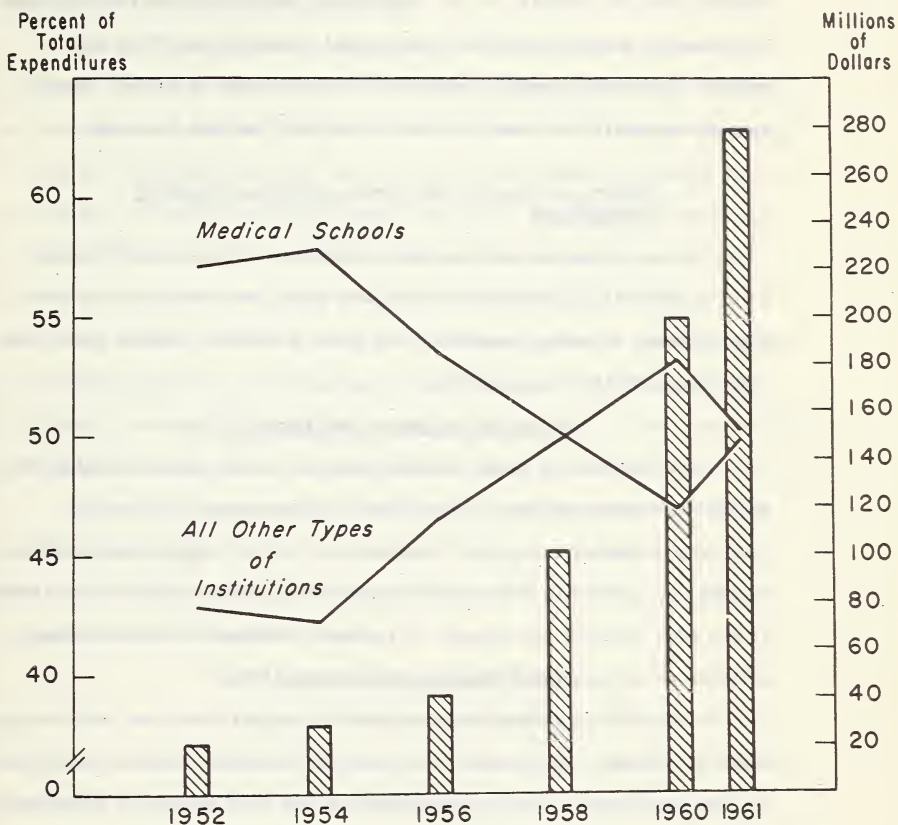
SOURCE: National Institutes of Health



\$ 890 MILLION

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INSTITUTIONS OTHER THAN MEDICAL SCHOOLS NOW RECEIVE HALF OF NIH EXTRAMURAL RESEARCH SUPPORT



SOURCE: National Institutes of Health

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still comprise a significant share of the total spent for medical research, (2) industrial medical research is financed almost exclusively from company funds in contrast to the substantial dependence upon Federal funds of virtually every other area of industrial research, and (3) a wide variety of private sources, uninhibited by the growth of Federal funds, contribute significant sums for the financing of medical research.

C. Factors Influencing the Growth of Medical Research Expenditures

It is recognized that economic capability is but one of the many forces that will influence the magnitude, pace, and composition of the future growth of medical research. At least four major factors other than economic capability are involved.

Human Wants, Needs, and Expectations

The major force behind medical research is the people's demand for healthier, more productive, longer lives. Science can alleviate the suffering, tragedy, and social loss involved in the toll of human disease, disability, and death. To a considerable extent these demands are reflected in the high priority for support of research relating to such pressing problems as cancer, heart disease, and mental illness.

The focus of medical research shifts constantly to meet the changing needs of society. For example, as the major infectious diseases have been brought under control, increasing attention has been devoted to research on

the chronic diseases which are now the leading causes of death (chart 9).

As another example, the Nation now faces pressing needs for research in all aspects of environmental health. ^{1/}

Medical research in the next decade will face new and exacerbated problems occasioned by the pace and tensions of urbanization; opportunities to minimize morbidity and maximize physical and mental well-being especially during the early and the later years of life; the demands for better health on the part of under-privileged people throughout the world; the mounting pressure, strain and tension occasioned by the burdens of industrialized society; the hazards of nuclear energy and chemical agents; and the adaptation of man to life in outer space and other planets. In addition to the needs presented by the changing physical and social environment, the progress of research at the cellular and molecular levels is bringing medical research closer and closer to the enigmas of life, reproduction, and death.

Thus far, the magnitude and substance of medical research has been influenced primarily by "domestic" demand. The opportunities are rising for substantial undertakings to advance the national interest in medical research in the international field.

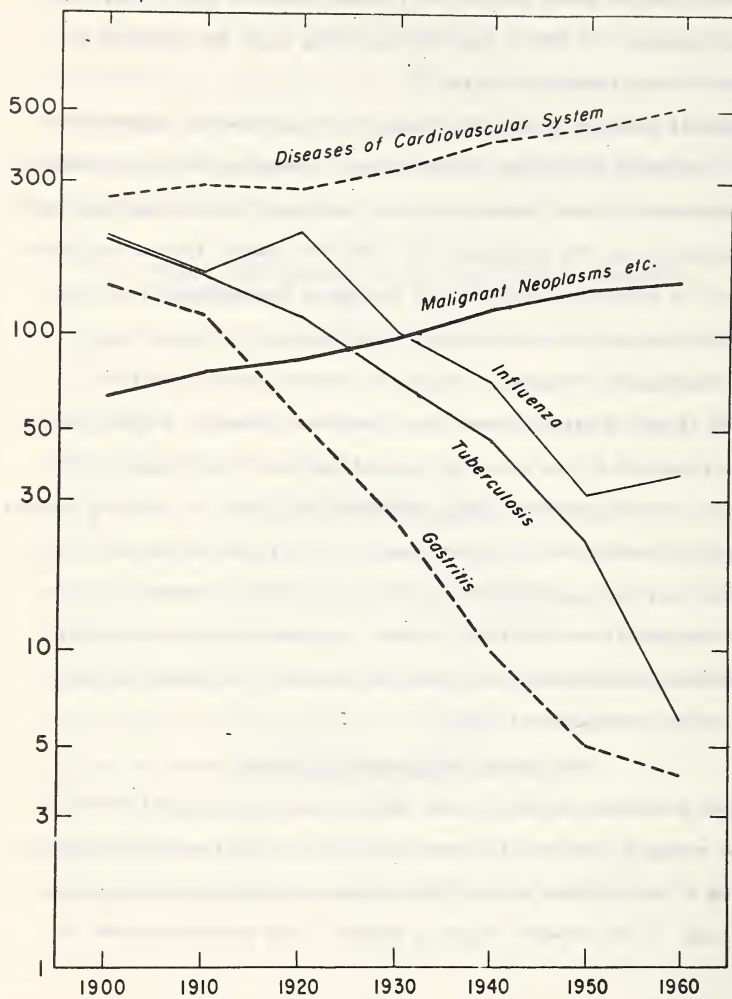
The Thrust and Promise of Science

Just as earlier centuries have been dominated by cultural revivals, religious struggle, and political and industrial revolution, the scientific revolution is the hallmark of the 20th Century. Medical research is an integral part of the forward thrust of science. The accelerated pace of

^{1/} Report of the Committee on Environmental Health Problems to the Surgeon General, U. S. Department of Health, Education and Welfare, Public Health Service, November 1, 1961.

-132-
Chart 9
CAUSES OF DEATH, 1900-1960

Death Rate
per 100,000 Population



SOURCE: National Office of Vital Statistics

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discovery spurs the need for more effective translation of research findings into diagnostic and therapeutic agents and procedures. Further discoveries will provide the basis for even greater achievement. The prospect of victory over major killers will compel greater and broader effort, and the area of fruitful scientific inquiry is limitless.

The Resources for Medical Research

The specific problem of resources and requirements for medical research must be viewed within the context of: (1) the resource base provided by economic and population growth; (2) the number and distribution of physicians and scientists currently engaged in medical research; (3) the probable dimensions of manpower requirements to meet research needs; (4) the probable output of M.D.'s and Ph.D.'s trained for and motivated toward medical research; and (5) the need for new facilities to alleviate existing inadequacies and to meet future demand.

The national capacity and rate of production of such resources can be materially influenced by national objectives. Specific action to enlarge existing and create new teaching and research facilities and to attract trained people to work in the sciences related to medical research can be undertaken.

National Intention, Policy and Action

In the final analysis, the decisive determinants affecting medical research in the Nation are the actions of the Federal Government. This is exemplified in what has happened to the programs of the National Institutes

of Health. A few years ago these programs truly constituted a means of grants-in-aid, assisting the research and investigative activities of universities and research institutions in the field of health and medicine. However, as a consequence of a Congressional determination that adequate financial support is essential to the advancement of medical research, these programs have moved to a role of major support for research in categorical disease areas as a coordinated attack upon pressing public health problems. Today, the research activities of the National Institutes of Health constitute the single most powerful force for the creation, development, and direction of the Nation's medical research effort and potential. What we have witnessed is the transformation of medical research into a national responsibility.

D. The Future Growth of Medical Research

The primary factor determining medical research manpower needs is the growth of medical research itself. Research expenditures constitute the best single quantitative measure of such growth. The Nation's medical research expenditures have risen from less than \$90 million in 1947 to \$890 million in 1961. ^{1/} Such growth feeds upon itself and has unleashed a terrific impetus for further expansion through:

- (1) The continued growth of the NIH research grant program.
- (2) A three-quarter billion dollar expansion of health research facilities which has been catalyzed by \$150 million of Health Research Facilities funds.

^{1/} The Nation's expenditures for medical and health-related research actually exceeded \$1 billion in 1961. The increase reflects better coverage of Federal expenditures and expenditures in the medical supply and medical electronics sectors of industry. As soon as possible, the basic series on the Nation's expenditures for medical and health-related research from 1947-1961 will be adjusted to reflect improvements in coverage since 1957. However, the \$890 million estimate for 1961 is retained here in order to permit comparison with prior years.

(3) Support of research in literally hundreds of separate nuclei of research competence.

(4) Creation of clinical research centers.

(5) Establishment of long-range research programs in areas such as aging, perinatal mortality, human population laboratories, and viral origins of cancer.

(6) Spread of medical research into social problem areas such as juvenile delinquency, alcoholism, mental retardation and school health.

(7) Pace of research growth in the pharmaceutical, medical supply, and medical electronics industries.

(8) Stimulation of additional manpower needs in the physical and behavioral sciences to keep pace with research opportunities and to provide training requisite for research careers. The kinds of research manpower needed shift in consonance with program emphasis and the ever-enlarging scope of research opportunities.

Taking account of these long-term trends and of the vitality of the varied forces that call for continued expansion of the Nation's medical research effort, it seems reasonable to infer that expenditures for medical research can be expected to grow in consonance with the Nation's total outlay for all research and with the gross national product. This offers a convenient and useful means of relating medical research expenditures in the aggregate to economic capability. This means of projecting medical research expenditures was adopted in two national studies of medical research carried out in the past three years. In June 1958, the Secretary's Consultants on Medical Research and Education (Bayne-Jones Committee), composed of a group of outstanding private citizens in industry, medicine, and education,

submitted their report to the Secretary of Health, Education, and Welfare. Based upon assumptions about (1) the present level of medical research, (2) the proportion of such research financed by the Federal Government, and (3) the growth of the economy, this report set forth two fundamental policy guides:

1. The Nation's medical research effort will not level off, .
but will expand at a rate greater than the rate of growth
of the Nation's economy.
2. The Federal Government must provide at least half of the
financial support for this growing national medical research
effort.

In April 1960, another select group, the Committee of Consultants on Medical Research (Jones Committee) submitted its report Federal Support of Medical Research to the Senate Subcommittee on Appropriations for the Departments of Labor and Health, Education, and Welfare. In presenting its findings on the adequacy of Federal support, the Committee stated that:

"The funds provided by the Federal Government in support of medical research over the past 15 years have been substantial. Although generously increased in recent years, they have not kept pace with new opportunities in research which have developed, largely as a result of the very advances which the funds expended in the past have generated."

E. Projections of Future Growth of Medical Research, 1965-1970.

Both the Bayne-Jones and the Jones committees faced up to the problem of projecting probable levels of the Nation's medical research expenditures in the future. Each relied upon the same method; both regarded these projections as a useful framework for long-range planning but cautioned against treating them as rigid targets for budgetary purposes.

The Bayne-Jones report estimated that the Nation's expenditures for medical research would reach \$1 billion in 1957-1958 dollars by 1970. The Consultants cautioned that their projections were conservative. Actual expenditures for medical research in 1957-60 have far outstripped the trend line aimed at the \$1 billion level for 1970. The estimate of \$1 billion for 1970 developed in the Bayne-Jones Report will, in fact, be reached in 1962. This level would, of course, be exceeded when the time series is revised to reflect expanded coverage of the Federal and industry sectors.

The Jones Committee expressed its belief that by 1970 the total support of medical research in the United States will probably require annual expenditures of \$3 billion. In arriving at this estimate, the Committee utilized projections which have been developed by the Resources Analysis Section, Office of Program Planning, NIH, indicating a possible range of research expenditures in 1970, of \$2.8 billion to \$3.3 billion.

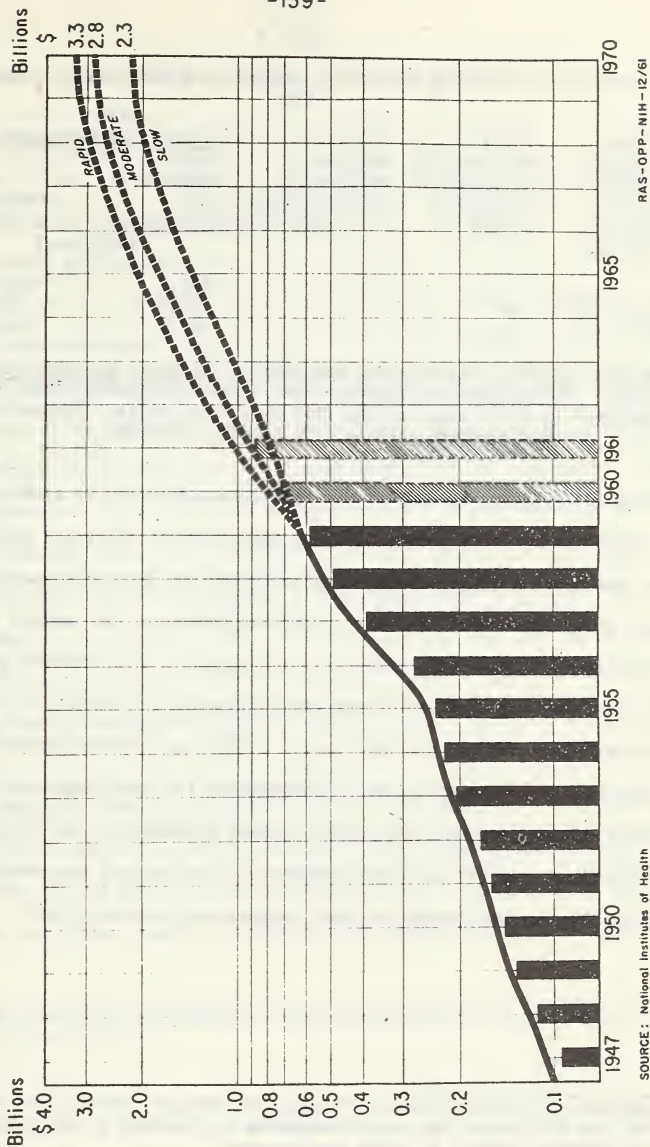
Such projections are useful in establishing probable ranges of future expenditures in terms of general orders of magnitude; they are essential to any appraisal of the probable future demand for research manpower. Inevitably, such projections draw upon past experience, take account of prevailing trends, and then reflect the best judgment of the person or institution making the projection. The crucial question is: What is the probability that the projections provide a sufficiently close forecast of the future as to be useful in planning policies and developing programs?

While only the historian of the future can give us the final answer to this question, we can: (1) examine experience since the projections were developed, (2) scrutinize critically the assumptions used in arriving at the alternative projections, and (3) consider the influence of other factors bearing upon the growth of medical research.

The alternative projections for slow, moderate, and rapid growth in expenditures for medical research utilized by the Jones Committee were made in June 1959. It is interesting to see the relationship of actual expenditures in 1960 and 1961 to these projections (chart 10).

Chart 10

NATIONAL EXPENDITURES FOR MEDICAL RESEARCH, 1947-1959 AND ALTERNATIVE PROJECTIONS, 1960-1970



SOURCE: National Institutes of Health

RAS-OPP-NIH-12/61

Table 6

Alternative Projections of Medical Research and Development Expenditures,
1970

Gross National Product Growth Rate 1/ Percent	Total Research and Development as Percent of GNP	Medical Research as Percent of Total Research and Development	1970 <u>Alternative Projections</u>	
			Total Research and Development (billions)	Medical Research
A-Slow 4.5	6	5	\$46.0	\$2.3
B-Moderate 5.0	6	6	47.5	2.8
C-Rapid 5.0	6	7	47.5	3.3

1/ Based on the National Planning Association, National Economic Projections Series. The NPA studies suggest a GNP of \$790 billion by 1970. As developed in 1959, based on the 1958 GNP, this implies a growth rate of 5%; it implies a growth rate of 4.5% based on 1960 GNP.

As indicated in Chart 10, estimated national expenditures for 1960 and 1961 exceed the moderate growth line but fall short of the rapid growth slope.^{1/} Taking into account Congressional appropriations for medical research in 1962, there is every indication that this year's expenditures for medical and health-related research will rise still further above the moderate growth line. Thus, experience over the past three years suggests the utility of alternative projections that identify probable ranges rather than predict precise targets.

This method necessarily entails assumptions for three variables:

(1) gross national product, (2) total national expenditures for research and development, and (3) national expenditures for medical and health-related research. The current trends in these factors are examined below:

^{1/} Expenditures actually rise well above the moderate growth line in both 1960 and 1961, when the recent expansion in coverage of the Government and industry sectors is taken into account.

Rate of Increase of Gross National Product

Gross national product has grown at the compound rate of 3 percent per year since 1900. However, a projection suitable for economic planning purposes cannot be derived simply by observing the average for the past fifty years and carrying the process ahead to a future year such as 1965 or 1970. The most obvious reason is that the past half-century saw one disastrous depression and two world wars. It is reasonable to look forward to a future without catastrophic depressions of the kind that started in 1929, and it is also clear that a third world war would bear no real resemblance to the first two. But even apart from the effects of these catastrophies, the long-term substantial record of past American growth would have no simple relation to its probable behavior in the future. This is reflected in the National Planning Association's first full report on economic projections in 1959 when it estimated that "the total production of goods and services is likely to rise.....to more than \$600 billion in 1965 and to approximately \$800 billion in 1970....expressed in the price level of 1958...

"For the economy as a whole, the projections imply an average rate of growth in total production of about 4.2% per year. This is approximately the same rate of growth as that experienced in the immediate postwar decade, but higher than the average rate of 3% in the last 50 years." ^{1/}

^{1/} National Planning Association, National Economic Projections, 1962-1965; 1970; 1959, p. 1

In its most recent release, the National Planning Association estimates that the annual average growth for the next decade will be over 4.5 percent. It projects an average annual growth and total output to 1971 of 4.6 percent from the actual 1960 base point.^{1/}

Perhaps, more important than these estimates is the Administration's commitment to more rapid growth of GNP. President Kennedy in June 1961, responding to Premier Khrushchev's challenge, asserted that a 4.5 percent growth rate is well within the capabilities of the United States economy.^{2/} The President's Chairman of the Council of Economic Advisers, Dr. Walter Heller, appearing before the Joint Economic Committee in March 1961, stated that:

"Starting with a 1960 potential GNP of \$535 billion and assuming constant prices, growth at 3.5, 4, and 5 percent per year would lead to aggregate output levels of \$755 billion, \$792 billion, and \$871 billion respectively in 1970."^{3/}

Thus, the 5 percent growth rate shown on Table 6 which was projected from 1958 GNP would represent only a 4 percent growth rate when projected from 1960 potential GNP or a 4.5 percent growth rate from 1960 actual GNP. These assessments of feasibility, combined with the Administration's commitment to a more rapid rate of growth, suggest that the \$790 billion GNP for 1970 is well within the realm of probability.

^{1/} National Planning Association, National Economic Projections Series, 1961, pp. V, 5.

^{2/} President's news conference, June 28, 1961, as reported in New York Times, June 29, 1961.

^{3/} Hearings Before the Joint Economic Committee, January 1961 Economic Report of the President and the Economic Situation and Outlook, p. 340.

Research and Development as a Percent of GNP

Total national expenditures for research and development as a proportion of the gross national product trebled between 1940 and 1950 and then trebled again between 1950 and 1960 (see Table 1). If this rate of growth is sustained during the Sixties, by 1970 nearly one-tenth of the gross national product would be channeled into research activities. In 1959, when the projections shown in Chart 10 and Table 6 were developed, it seemed prudent to use a more modest estimate. Thus, it was assumed that total expenditures for research and development would double from 3 percent to 6 percent as a proportion of GNP during the Sixties, in contrast to the more explosive growth of the Forties and Fifties.

Medical Research as a Percent of Total Expenditure
For Research and Development

The Bayne-Jones Report assumed that medical research as a proportion of the total research and development would remain at the 1947-1957 average of 3.8 percent. Medical research has been in a period of rapid but steady growth. Increased Congressional appropriations, and philanthropic expenditures for medical research are evidence of the pressures in the society which have brought about this growth. These pressures are likely to intensify. The triumphs of medical research have been evident to all, but the great killers, such as cancer and heart disease, still remain to

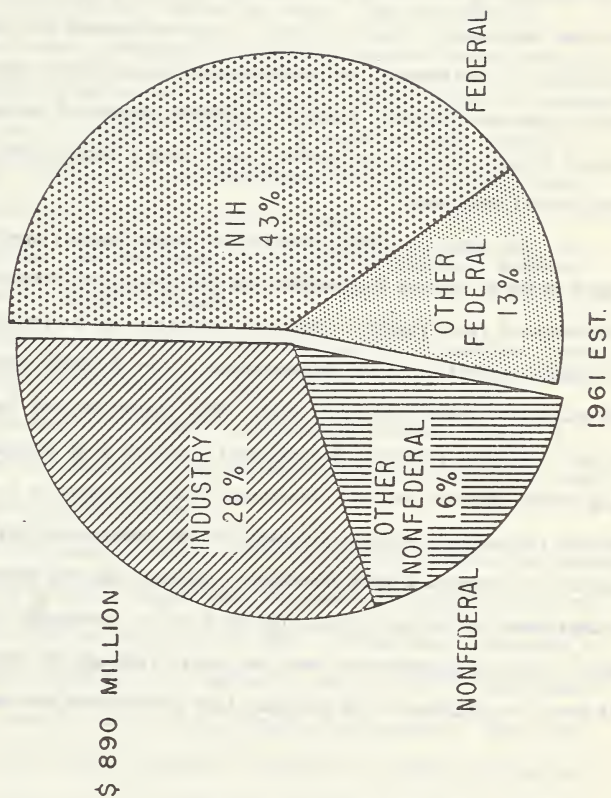
be conquered. In view of the dramatic contributions of medical research to mankind, it is reasonable to assume that public concern and interest may stimulate medical research to grow more rapidly than other areas of scientific inquiry.

Since 1959 when the projections shown in Chart 8 were made, a number of significant developments have occurred:

1. Research appropriations for the National Institutes of Health have grown from \$202 million to \$556 million in 1962. Despite this substantial increase, it should be emphasized that the Nation's medical research effort extends beyond the scope of NIH appropriations. In 1961 the National Institutes of Health supports slightly over 40% of the Nation's medical research, all other sources account for the remaining 60% (chart 11).

2. The Nation has embarked upon a \$30 billion ten-year space program which will involve increasingly heavy outlays for medical research and space biology concerned with the protection of man in space flight. This involves studies on the atmospheric pressure needed by humans in space capsules, the permissible range of temperature and humidity, the remote monitoring of the physical, chemical and mental functioning of individual crew members, and psychological reactions to launching speeds, isolation, and confinement. In the decade ahead, it is quite probable that this program will accelerate more rapidly than the total national medical research

Chart II
NIH FUNDS AS A PROPORTION OF
NATION'S MEDICAL RESEARCH SUPPORT



SOURCE : National Institutes of Health

RAS-OPP-NIH-12/61

effort. At the same time, research of the Space Agency is likely to foster approaches and devise instrumentation equally applicable to the study and observation of man on earth. This development has already taken place in instrumentation and biomedical engineering. Hence, the space program not only will comprise a growing segment of Federally-financed medical research; it probably will have a booster effect upon other Federal programs.

3. The Veterans Administration and other Federal agencies have stepped up their support for medical and health-related research in the furtherance of their mission; continued expansion can be anticipated. For example, medical research expenditures of the Veterans Administration have multiplied three-fold since 1954. That agency is just beginning to tap the tremendous potential for clinical research on a nationwide basis using common research design. The Atomic Energy Commission has steadily expanded its medical research programs and has constructed research hospitals in connection with Brookhaven, Argonne, and Oak Ridge activities. The Department of Defense has maintained a fairly consistent level of medical research expenditures over the years, although the composition of this level has shifted as old problems have been solved and new ones have

arison. As appropriations for the National Science Foundation have mounted in recent years, that agency has greatly increased its support of basic research directly related to health. The Department of Agriculture conducts fundamental and applied research on the production and utilization of agricultural products and on the control of diseases and insect pests of animals and plant. A portion of this research undertaken in fulfillment of that Department's historic mission also constitutes research directly related to health. 1/

4. States, and the larger cities have substantially expanded their support for medical research.

5. Private sources through Foundations, health agencies, bequests, and gifts have steadily increased their support in this area.

6. Industry's investment in research has mounted sharply in pharmaceutical and chemical firms and has extended to the medical supply and medical electronics sectors.

As a consequence of these activities, medical research has mounted as a proportion of total expenditures for research and development from 4.7 percent in 1959 to 5.6 percent in 1961. As indicated previously on page 14, actual expenditures in 1961 will exceed \$1 billion which would represent 6.2 percent of the total instead of 5.6 percent. Thus, the slow growth line on Chart 8 implies a decrease in medical research as a proportion of the total, the moderate growth line calls for a slight

1/ - "Health Activities of the Federal Government" Report of the Senate Committee on Government Operations by the Subcommittee on Reorganization and International Organizations, Senate Report No. 142, 87th Congress, 1st Session, March 30, 1961, p. 176.

increase in medical research as a proportion of the total, and the rapid growth line calls for a larger increase -- approximately one-tenth of one percent more a year -- in medical research as a proportion of the total.

In developing these projections of total national expenditures for medical and health-related research, no attempt has been made to apportion the projection between Federal and non-Federal expenditures. It is desirable to maintain a balance between public and private sources of support to avoid the potential perils of over-dependence upon Federal support. Diversified sources of support contribute most fruitfully to the nourishment of science in a free, pluralistic society. Diversity assures the scientist of the freedom imperative for the progress of research; it enables each organization to exercise its best judgment in supporting research of greatest relevance to its program goals; and it assures greater stability by providing a broader base to absorb the shock of major shifts in interests and financial capacity.

However, it cannot be emphasized too strongly that the end--the objective--is adequacy; diversity is a means. The national interest calls for Federal initiative and support when needs are sufficiently urgent or the opportunities unusually promising. To sacrifice adequacy in order to adhere to some fixed formula for diversity would be damaging indeed. Consequently, while it is desirable to assure diversity among Government and all other sources of support, it would be unwise to commit national policy to a rigid formula that would freeze the present balance between these sources.

Summary

A projection of \$3 billion for medical research in 1970 seems reasonable, based upon this examination of the feasibility of the assumptions used. If it is assumed that the Nation's medical research expenditures will, in fact, approach this order of magnitude by 1970, such expenditures may reach \$1.8 billion in 1965. This projection falls midway between the moderate growth line of \$2.8 billion and the rapid growth line of \$3.3 billion. This projection is limited to current expenditures for medical research. It does not include outlays for research plant and equipment or the costs of research training both of which are viewed as capital expenditures for research resources.

The \$3 billion projection for 1970 for medical and health-related research is not set forth as a goal or target but rather as a reasonable approximation within a probable range of \$2.8 billion to \$3.3 billion. Many factors will influence the growth of research expenditures during the Sixties. However, for purposes of estimating research manpower requirements, it is assumed that the \$3 billion projection constitutes a reasonable and feasible frame of reference. Attainment of this projection would call for a trebling in national expenditures for medical and health-related research.

A Note on Inflation

The \$3 billion projection for 1970 which was prepared in 1959 is expressed in 1958 dollars. However, expenditures for medical research are usually reported in absolute figures without any adjustment for erosion in the purchasing power of the dollar. Consequently, assuming continuation of

the 1954-1958 rate of inflation, \$3 billion in 1970 would purchase only \$2.3 billion of research, expressed in 1958 dollars. This means that, if the 1954-58 rate of inflation continues through the Sixties, the \$3 billion projection for 1970 stated in 1958 constant dollars may range between \$4 billion and \$4.8 billion, expressed in 1970 current dollars.^{1/}

^{1/} The lower range reflects the result of using the GNP deflator; the upper range is the product of the Government purchases of goods and services deflator.

List of Appendix Tables

<u>Table No.</u>		<u>Page No.</u>
1	Scientific and Professional Manpower Engaged in Medical and Health-Related Research by Sector, 1954, 1958, and 1960	154
2	Scientific and Professional Manpower Engaged in Medical and Health-Related Research, Sector and Level of Training, 1958, 1960	158
3	Scientific and Professional Manpower Engaged in Medical and Health-Related Research, by Field, 1954, 1958, 1960	160
4	Scientific and Professional Manpower Engaged in Medical and Health-Related Research, by Sector and Field, 1960	161
5	Output of M.D.'s and Science Ph.D.'s in the U.S., 1946-1960, by Field	162
6A	Model for Estimating Annual Flow of M.D.'s Entering into the Medical Research Manpower Supply from Those Awarded M.D. Degrees, 1945-65 (Shows Research Input in the years 1950-1970)	163
6B	Model for Estimating Cumulative Flow of M.D.'s Entering into the Medical Research Supply from Those Awarded M.D. Degrees, 1945-65 (Shows Research Input in the Years 1950-1970)	164
7A	Model for Estimating Annual Flow of Ph.D.'s in the Biosciences Entering into the Medical Research Manpower Supply from Those Awarded Ph.D. Degrees 1947-67 (Shows Research Input in the Years 1950-1970)	165
7B	Model for Estimating Cumulative Flow of Ph.D.'s in the Biosciences Entering into the Medical Research Manpower Supply from Those Awarded Ph.D. Degrees 1947-67 (Shows Research Input in the Years 1950-1970)	166

List of Appendix Tables

<u>Table No.</u>		<u>Page No.</u>
8A	Model for Estimating Annual Flow of Ph.D.'s in the Basic Medical Sciences into the Medical Research Manpower Supply from Those Awarded Ph.D. Degrees 1947-67 (Shows Research Input in the Years 1950-70)	167
8B	Model for Estimating Cumulative Flow of Ph.D.'s in the Basic Medical Sciences into the Medical Research Manpower Supply from Those Awarded Ph.D. Degrees, 1947-67 (Shows Research Input in the Years 1950-70)	168
9A	Model for Estimating Annual Flow of Ph.D.'s in the Other Biosciences Entering into the Medical Research Manpower Supply from Those Awarded Ph.D. Degrees 1947-67 (Shows Research Input in the Years 1950-1970)	169
9B	Model for Estimating Cumulative Flow of Ph.D.'s in the Other Biosciences Entering into the Medical Research Manpower Supply from Those Awarded Ph.D. Degrees, 1947-67 (Shows Research Input in the Years 1950-1970)	170
10A	Model for Estimating Annual Flow of Ph.D.'s in Psychology into the Medical Research Manpower Supply from Those Awarded Ph.D. Degrees 1947-67 (Shows Research Input in the Years 1950-1970)	171
10B	Model for Estimating Cumulative Flow of Ph.D.'s in Psychology into the Medical Research Manpower Supply from Those Awarded Ph.D. Degrees, 1947-67 (Shows Research Input in the Years 1950-1970)	172
11	Distribution of Physicians by Type of Activity Showing Percent Change, 1949 and 1959	173
12	Ph.D.'s Awarded in the Sciences by Field, 1950-1960 and Estimated Output, 1961-1967	174
13	Projections of Master's Degrees in Nursing, Social Work and Public Health, 1961-1970	175
14	Output of M.D.'s from U.S. Schools, 1947-1960 with Projections for 1961-1970	176
15	Graduates of U. S. Medical Schools and U. S. Graduates of Foreign Medical Schools Receiving U. S. Licenses, 1950-1960	177

List of Appendix Tables

<u>Table No.</u>		<u>Page No.</u>
16	Estimated Output of M.D.'s from U. S. Medical Schools and Additions to the U. S. Supply from Graduates of Foreign Medical Schools, 1961-1970	178
17	Projections of Ph.D. Output in the Sciences, 1961-1970	179
18	Projection of Ph.D. Output in the Biosciences, by Discipline, 1961-1970	182

Appendix Table 1

Scientific and Professional Manpower Engaged in Medical and Health-Related Research by Sector, 1954, 1958 and 1960

Sector	Increase						
				1954-1960		1958-1960	
	1954	1958	1960	Number	Percent	Number	Percent
Total	<u>19,200</u>	<u>34,600</u>	<u>39,700</u>	<u>20,500</u>	<u>106.8</u>	<u>5,100</u>	<u>14.7</u>
Government	<u>3,700</u>	<u>6,900</u>	<u>7,800</u>	<u>4,100</u>	<u>110.8</u>	<u>900</u>	<u>13.0</u>
Federal	3,250	5,500	6,100	2,850	87.7	600	10.9
State and local	450	1,400	1,700	1,250	277.7	300	21.4
Industry	3,400	6,500	7,200	3,800	111.8	700	10.8
Universities and research institutes	12,100	21,200	24,700	12,600	104.1	3,500	16.5
<u>Percent distribution</u>							
Total	<u>100.0</u>	<u>100.0</u>	<u>100.0</u>	<u>100.0</u>		<u>100.0</u>	
Government	<u>19.3</u>	<u>19.0</u>	<u>19.7</u>	<u>20.0</u>		<u>17.7</u>	
Federal	<u>16.9</u>	<u>15.9</u>	<u>15.4</u>	<u>13.9</u>		<u>11.8</u>	
State and local	2.4	4.0	4.3	6.1		5.9	
Industry	17.7	18.8	18.1	18.5		13.7	
Universities and research institutes	63.0	61.3	62.2	61.5		68.6	

See pages 155-157 for Notes on Sources.

Notes on Sources for
1954, 1958, and 1960 Estimates

Sectors:

1954

Government - Based upon Scientific Manpower in the Federal Government, 1954, National Science Foundation, 1957, as reported for civilian personnel on p. 84 (clinical and biosciences), p. 75 (chemistry), p. 92 (psychology), and p. 181 for all military personnel (all fields). Estimates for State and local government made by Resources Analysis Section, Office of Program Planning, NIH, taking into account the fact that the State of New York alone reported more than 336 professional man years engaged in medical research. See Science and State Government in New York, prepared for the National Science Foundation by the Institute for Research in the Social Sciences, University of North Carolina, Chapel Hill, N.C., p. 123.

Industry - Based upon Industrial Research Laboratories of the United States, Publication 379, National Academy of Science, National Research Council, 1955. The general validity of this estimate is confirmed by Trends in Employment of Laboratory Personnel in the Drug and Medicines Industry, 1945-1955, a Report prepared for the National Institutes of Health by Galaxy Inc., March, 1958. This report shows a total of 4,200 professional chemists and life scientists in 1955 (one year later than the 1954 period shown in Appendix Table 1).

Universities and

Research Institutes - The data on university manpower engaged in medical and health-related research are based on Scientific Research and Development in Colleges and Universities, Expenditures and Manpower, 1953-54, National Science Foundation NSF 59-10, 1959, Appendix Table A-28. Estimate of total in medical and health-related research made by Resources Analysis Section, Office of Program Planning, NIH, and includes all clinical scientists, roughly 85 percent of the biological scientists, and approximately 750 psychologists, chemists, social scientists, and agricultural scientists, taking into account the distribution of NIH grant support for medical research in academic institutions by field in 1954.

The 1954 data include a conservative estimate of 1,900 in (1) independent non-affiliated hospital, (2) contractor operated research centers such as Oak Ridge and Brookhaven, (3) clinics such as Menninger and Mayo, (4) medical research institutes such as Rockefeller and (5) community agencies, especially in the mental health field.

1958

Sectors:

Government - Based upon National Institutes of Health Survey of Federal Expenditures and Manpower in Medical Research, 1958. Totals for the Veterans Administration are taken from "Health Activities of the Federal Government", Report of the Senate Committee on Government Operations by the Subcommittee on Reorganization and International Organizations, Senate Report No. 142, 87th Congress, 1st Session, March 30, 1961, p. 234 (the V.A. data reported to the Humphrey Committee were limited to manpower paid from funds separately budgeted for research and, hence, were preferable to figures reported to NIH which covered all V.A. manpower engaged in medical research, irrespective of source from which funds were budgeted).

Data for State and local government estimate were obtained by National Institutes of Health Pilot Study of Medical and Health-Related Research Expenditures and Manpower in Five States, 1958. This study included: New York, California, Michigan, Connecticut, and Florida. The estimate represents the actual total reported by these five states only. It is, however, compatible with medical research expenditure data which, in 1958, were also restricted in coverage to these same five states.

Industry - Based upon Pharmaceutical Manufacturers Association Survey of Manpower in Drug or Medical Research and Development, 1959.

Universities and

Research Institutes - The data on university manpower engaged in medical and health-related research are based on: (1) National Science Foundation, "Scientists and Engineers in Research and Development in Colleges and Universities, 1958", Reviews of Data on Research and Development No. 27, April 1961. This bulletin reports nearly 17,000 life scientists engaged in research in universities in all program areas. Estimate of total in medical and health-related research made by Resources Analysis Section, Office of Program Planning, NIH, and includes all clinical scientists, roughly 85 percent of the biological scientists, and approximately 1,800 from psychology, chemistry, the social sciences, and other disciplines taking into account the distribution of NIH research grant support for medical research in academic institutions by field in 1957, (2) National Institutes of Health Survey of Federal Expenditures and Manpower in Medical Research, 1958, provides coverage of AEC contract operated research centers, (3) National Institutes of Health National Survey of Expenditures and Manpower in Medical and Health-Related Research in Hospitals, 1958, provides coverage of both non-affiliated and affiliated hospitals not included in the NSF University Survey.

(4) Special analyses of expenditures and manpower engaged in medical and health-related research in independent nonprofit research institutes.

1960

Sectors:

Government - Based upon (1) detailed field by level of training analysis of scientific manpower engaged in the intramural research programs of the National Institutes of Health, (2) National Academy of Sciences - National Research Council, Survey of Medical Research in the Veteran's Administration, June 30, 1960. and (3) estimates for military and other Federal agencies applying distribution obtained in National Institutes of Health Survey of Federal Expenditures and Manpower in Medical Research, 1958, to 1960 intramural levels.

State and local government estimate is based upon National Institutes of Health Pilot Study of Medical and Health-Related Research, 1958, taking into account sharp increases in medical research expenditure levels.

Industry - Based upon Pharmaceutical Manufacturers Association Survey of Manpower in Drug or Medical Research and Development, 1960.

Universities and

Research Institutes - Estimated by National Institutes of Health, taking into account (1) increment of new investigators engaged in grant or contract supported medical research in universities with trends verified against preliminary data obtained by the National Science Foundation Survey of University Manpower, 1961, and made available through the courtesy of that agency for a matched group of 44 universities reporting to the Foundation both in 1958 and in 1961, (2) manpower data published in annual reports for AEC contractor-operated research centers and for leading affiliated and nonaffiliated hospitals not covered by the NSF university survey, and (3) special analyses of manpower engaged in medical and health-related research in independent research institutes.

Resources Analysis Section
Office of Program Planning, NIH
January 1962

Appendix Table 2

Scientific and Professional Manpower Engaged in Medical and Health-Related Research, by Sector and Level of Training, 1958, 1960

Sector	1958					1960				
	Doctoral					Doctoral				
	M.D., D.D.S., D.V.M.					M.D., D.D.S., D.V.M.				
	Total	Ph.D. Sc.D.	Less than doctoral M.S., M.P.H., M.A., B.S., A.B.			Total	Ph.D. Sc.D.	Less than doctoral M.S., M.P.H., M.A., B.S., A.B.		
Total	34,600	24,690	14,700	2,910	39,700	29,400	18,400	10,000	10,300	
Government	6,900	3,740	2,000	3,160	7,800	4,250	1,975	2,275	3,550	
Federal	5,200	3,000	1,700	2,500	6,100	3,350	1,450	1,900	2,750	
State and local	1,400	740	300	660	1,700	900	525	375	800	
Industry	6,500	2,450	400	4,050	7,200	2,750	550	2,200	4,450	
Universities and research inst.	21,200	18,500	7,850	2,700	24,700	22,400	8,875	13,525	2,300	
Percent distribution by sector										
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	
Government	19.9	15.2	17.4	31.9	19.7	14.5	17.3	12.6	34.5	
Federal	15.9	12.2	13.0	25.2	15.4	11.4	12.7	10.5	26.7	
State and local	4.0	3.0	4.4	6.7	4.3	3.1	4.6	2.1	7.8	
Industry	18.8	9.9	4.0	40.9	18.1	9.3	4.8	12.2	43.2	
Universities and research inst.	61.3	74.9	78.6	27.2	62.2	76.2	77.9	75.2	22.3	
Percent distribution by level of training										
Total	100.0	71.4	28.9	42.5	100.0	74.1	28.7	45.4	25.9	
Government	100.0	54.2	25.2	29.0	100.0	54.5	25.3	29.2	45.5	
Federal	100.0	54.5	23.6	30.9	100.0	54.9	23.8	31.1	45.1	
State and local	100.0	52.8	31.4	21.4	100.0	53.0	30.9	22.1	47.0	
Industry	100.0	37.7	6.2	31.5	100.0	38.2	7.6	30.6	61.8	
Universities and research inst.	100.0	87.3	37.0	50.3	100.0	90.7	35.9	54.8	9.3	

See page 159 for Notes on Sources.

Resources Analysis Section
Office of Program Planning, NIH
January 1962

Notes on Sources
1958 and 1960

For detailed identification of sources see Notes for Appendix Table 1.

Sectors:

Government - National Institutes of Health Survey of Federal Expenditures and Manpower in Medical Research, 1958, National Institutes of Health, Pilot Study of Medical and Health-Related Research Expenditures and Manpower in Five States, 1958, special analysis by level-of-training of manpower engaged in NIH intramural research programs, 1960, and National Academy of Sciences - National Research Council, Survey of Medical Research in the Veteran's Administration, June 30, 1960.

Industry - Pharmaceutical Manufacturers Association Annual Survey of Manpower in Drug or Medical Research, 1959 and 1960.

Universities and

Research Institutes - Distribution by level of training for medical researchers in universities, 1958, is derived from a sample of all professional workers on all active grants and contracts for medical research listed in the files of the Biosciences Information Exchange (now Science Information Exchange). The results were correlated with the distribution of research expenditures by academic departments and verified against the National Science Foundation Register of Scientists and Engineers. Distribution applied to 1958 university total derived from NSF Reviews of Data on Research and Development No. 27, modified by NIH estimate for participation of fields other than clinical sciences. Distribution by level of training for medical researchers in hospitals, research centers, and research institutes obtained by National Institutes of Health National Survey of Expenditures and Manpower in Medical and Health-Related Research in Hospitals, 1958, and Survey of Federal Expenditures and Manpower in Medical Research, 1958, (contractor operated research centers), and special analyses of manpower in medical research in independent research institutes. Estimates by level of training for 1960 are based primarily upon trends reported in NIH First-Time Grantee surveys.

Resources Analysis Section
Office of Program Planning, NIH
January 1962

Appendix Table 3

Scientific and Professional Manpower Engaged in Medical and Health-Related Research, by Field, 1954, 1958, 1960

	Number			Increase			
	1954	1958	1960	1954-1960		1958-1960	
				Number	Percent	Number	Percent
Total	19,200	34,600	39,700	20,500	106.8	5,100	14.7
Biomedical sciences	14,950	24,425	28,075	13,125	87.8	3,650	14.9
Clinical specialties	6,250	9,075	10,305	4,665	64.9	1,230	13.6
Dentistry		495	610			115	23.2
Biosciences	8,700	14,855	17,160	8,460	97.2	2,305	15.5
All other sciences	4,250	10,175	11,625	7,375	173.5	1,450	14.3
Physical sciences, mathematics and engineering		6,230	7,045			815	13.1
Social and behavioral sciences		2,765	3,255			490	17.7
Health professions and all other		1,180	1,325			145	12.3
Percent distribution							
Total	100.0	100.0	100.0	100.0		100.0	
Biomedical sciences	77.9	70.6	70.7	64.0		71.6	
Clinical specialties	32.6	26.2	26.0	22.7		24.1	
Dentistry		1.4	1.5			2.3	
Biosciences	45.3	43.0	43.2	41.3		45.2	
All other sciences	22.1	29.4	29.3	36.0		28.4	
Physical sciences, mathematics and engineering		18.0	17.8			16.0	
Social and behavioral sciences		8.0	8.2			9.6	
Health professions and all other		3.4	3.3			2.8	

See Appendix tables 1 and 2 for detailed presentation of sources for 1954, 1958, 1960. Further breakdown of "All Other Sciences" is not available for 1954. This breakdown was obtained, however, in each of the studies conducted, sponsored, or stimulated by the National Institutes of Health 1958-1960.

Resources Analysis Section
Office of Program Planning, NIH
January 1962

Appendix Table 4

Scientific and Professional Manpower Engaged in Medical and Health-Related Research by Sector and Field, 1960

Field	Total	Government			Industry	Universities and Research Ins
		Total	Federal	State & local		
Total	39,700	7,800	6,100	1,700	7,200	24,700
Clinical specialties	10,305	1,800	1,270	530	505	8,000
Dentistry	610	110	95	15	-	500
Biosciences	17,160	3,010	2,365	645	3,150	11,000
Physical sciences, mathematics, and engineering	7,045	1,045	985	60	3,300	2,700
Social and behavioral sciences	3,255	1,285	975	310	20	1,950
Health professions & all other	1,325	550	410	140	225	550
Percent distribution by field						
Total	100.0	100.0	100.0	100.0	100.0	100.0
Clinical specialties	26.0	23.1	20.8	31.2	7.0	32.4
Dentistry	1.5	1.4	1.6	0.9	-	2.0
Biosciences	43.2	38.6	38.8	37.9	43.8	44.5
Physical science, mathematics, and engineering	17.8	13.4	16.1	3.5	45.8	11.0
Social and behavioral sciences	8.2	16.5	16.0	18.2	0.3	7.9
Health professions & all other	3.3	7.0	6.7	8.3	3.1	2.2
Percent distribution by sector						
Total	100.0	19.7	15.4	4.3	18.1	62.2
Clinical specialties	100.0	17.4	12.3	5.1	5.0	77.6
Dentistry	100.0	18.0	15.6	2.4	-	82.0
Biosciences	100.0	17.5	13.8	3.7	18.4	64.1
Physical sciences, mathematics, and engineering	100.0	14.9	14.0	0.9	46.8	38.3
Social and behavioral sciences	100.0	39.4	30.0	9.4	0.6	60.0
Health professions & all other	100.0	41.5	31.0	10.5	17.0	41.5

See Appendix tables 1 and 2 for detailed presentation of sources.

Resources Analysis Section
Office of Program Planning, NIH
January 1962

Appendix Table 5

Output of M.D.'s and Science Ph.D.'s in the U.S., 1946-1960, by Field

Field	Years			
	Total 1946-60	1946-50	1951-55	1956-60
Total M.D.'s and science Ph.D.'s ^{a/}	163,634	41,850	58,354	63,430
M.D.'s	95,569	28,405	32,721	34,443
Ph.D.'s in the sciences	68,065	13,445	25,633	28,987
Biosciences	14,608	2,770	5,672	6,166
Basic medical sciences	7,716	1,245	3,025	3,446
Other biosciences	6,892	1,525	2,647	2,720
Mathematics, physical sciences and engineering	32,863	6,929	12,561	13,373
Mathematics	3,034	604	1,124	1,306
Chemistry	13,615	3,341	5,130	5,144
Physics	6,308	1,184	2,576	2,548
Engineering	7,663	1,384	2,928	3,351
All other	2,243	416	803	1,024
Social & behavioral sciences ^{a/}	18,782	2,973	6,957	8,852
Psychology	7,813	994	3,108	3,711
Sociology & anthropology	2,767	551	1,081	1,135
All other	8,202	1,428	2,768	4,006
Other science fields	1,812	773	443	596

SOURCE: M.D. data - JAMA 178:647 (table 14), 1961; 1946-1956 Ph.D. data from National Research Council, Office of Scientific Personnel, Doctorate Production in United States Universities, 1936-1956, publication 582, pp 6,7; 1957-1960 unpublished data supplied by the National Research Council.

^{a/} To insure comparability with the National Science Foundation coverage of Ph.D.'s in the sciences, history has been omitted from Ph.D. output in the social sciences, although this field normally is included in social science doctorate data published by the National Research Council and the Office of Education.

Resources Analysis Section
Office of Program Planning, NIH
January 1962

Appendix Table 6B

Model for Estimating Cumulative Flow of M.D.'s Entering into the Medical Research Manpower Supply from Those Awarded M.D. Degrees, 1945-65
(Shows Research Input in the Years 1950-70)

M.D. Entering Medical Research			Difference between																							
Degrees Awarded	Percent	Research Number	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1970	1970	
1945	5136	6	308	46	92	138	184	230	246	261	277	292	308	308	308	308	308	308	308	308	308	308	308	308	-	
1946	5826	6	350	52	105	157	210	262	280	297	315	332	350	350	350	350	350	350	350	350	350	350	350	350	19	
1947	6389	6	383		57	115	172	230	287	306	325	345	364	383	383	383	383	383	383	383	383	383	383	383	39	
1948	5543	7	388			58	116	174	232	290	310	329	349	368	388	388	388	388	388	388	388	388	388	388	19	
1949	5094	7	357				54	107	161	214	268	286	304	321	339	357	357	357	357	357	357	357	357	357	53	
1950	5553	8	444					67	133	200	266	333	355	377	400	422	444	444	444	444	444	444	444	444	89	
1951	6135	8	491						74	148	222	296	370	394	418	443	467	491	491	491	491	491	491	491	121	
1952	6080	9	547							82	164	246	328	410	437	465	492	520	547	547	547	547	547	547	219	
1953	6668	10	667								100	182	264	346	428	510	592	674	756	838	920	1002	1084	1166	529	
1954	6861	11	755									113	226	339	452	565	678	791	904	1017	1130	1243	1356	1469	367	
1955	6977	12	837										125	251	376	502	627	752	877	1002	1127	1252	1377	1502	712	
1956	6845	13	890											133	267	400	534	667	801	934	1067	1200	1333	1466	890	
1957	6796	13	883												133	265	398	530	662	795	927	1060	1193	1326	839	
1958	6861	14	961													144	288	432	576	720	864	1008	1152	1296	864	
1959	6860	14	960														144	288	432	576	720	864	1008	1152	816	
1960	7081	15	1062															159	318	477	636	795	954	1113	848	
1961	6994	15	1049																157	314	471	628	785	942	785	
1962	7150	15	1072																	161	322	483	644	805	644	
1963	7225	15	1084																		163	326	489	650	489	
1964	7350	15	1103																			165	330	330	330	
1965	7500	15	1125																				169	169	169	
U.S. Total			46	144	300	514	782	1086	1428	1814	2262	2788	3379	4034	4751	5525	6350	7227	8150	9116	10,117	11,148	12,201	8822		
Foreign Input			12	36	75	129	196	272	357	454	566	697	845	1008	1187	1381	1587	1806	2036	2277	2527	2785	3048	2203		
Total, New Entrants into Medical Research Manpower Supply			58	180	375	643	978	1358	1785	2268	2828	3485	4224	5042	5938	6906	7937	9033	10,186	11,393	12,644	13,933	15,249	11,025		

See annual flow model for notes on source and method.

Resources Analysis Section
Office of Program Planning, NIH
January 1962

Appendix Table 7A

Model for Estimating Annual Flow of Ph.D.'s in the Biosciences Entering into the Medical Research Manpower Supply from Those Awarded Ph.D. Degrees 1947-67
(Shows Research Input in the Years 1950-1970)

Ph.D. Degree Awarded Year	Entering Med. Resh		Year											Net Increment															
	Number	Med. Resh	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	Total	Average	
1947	420	326				66	65	66	32	33	32	32															82	8	
1948	552	434				87	86	87	44	43	44	43															202	20	
1949	719	568						114	114	114	57	56	57	56													301	31	
1950	820	647						129	129	129	65	65	65	65													392	39	
1951	916	730						146	146	146	73	73	73	73	73	73											488	49	
1952	1018	811									162	161	162	81	82	81	82										588	60	
1953	1258	1004										200	200	200	101	101	101	101	101	101	100						1009	101	
1954	1258	1003											200	200	201	100	100	100	100	100	98	98					1085	108	
1955	1222	985												198	197	198	198	198	198	198	197	197					116	116	
1956	1222	985													198	197	198	198	198	198	198	198	197	197			116	116	
1957	1250	1010														202	202	202	202	202	201	201	201	201	201			125	125
1958	1251	1009															201	201	201	201	201	201	201	201	201			125	125
1959	1226	985																201	201	201	201	201	201	201	201			125	125
1960	1346	1085																	201	201	201	201	201	201	201			125	125
1961	1403	1125																		201	201	201	201	201	201			125	125
1962	1545	1255																			201	201	201	201	201			125	125
1963	1724	1440																				201	201	201	201			125	125
1964	1849	1501																					201	201	201			125	125
1965	2030	1646																						201	201			125	125
1966	2187	1812																							201			125	125
1967	2352	1912																										125	125
U.S. Total			66	132	266	362	466	569	704	801	873	895	931				960	987	1002	1032	1088	1172	1237	1358	1481	1604	11941		1194
Foreign Input			11	27	48	65	85	105	130	149	164	169	178				184	189	193	199	212	230	246	266	292	317	2328		232
Total, New Entrants into Medical Research Manpower Supply			77	159	314	427	551	674	834	950	1037	1064	1109				1144	1176	1195	1231	1300	1402	1503	1624	1773	1921	14269		1426

NOTES ON SOURCE

SOURCE: Ph.D. output 1947-60 from National Academy of Sciences-National Research Council for years 1947-50; published in Postgraduate Medical Journal, 1961-65; (NSC) 1966-67; (NSC) 1968-69; (NSC) 1970-71; and 1972-73. Data for 1974 and 1975 have been made available by NRC to the National Institutes of Health. Projections, 1961-1970 developed by Resources Analysis Section, OPI, NIH. See Appendix Table 1f.

NOTES ON METHOD

1. Ninety percent of the Ph.D.'s in the basic medical sciences and 70 percent of those in the clinical sciences enter the medical research as independent investigators at some time during their careers.
2. There is a minimal 3-year lag between receipt of the Ph.D., subsequent postdoctoral training, and entrance into independent research.
3. In developing this model, it has been assumed that 60 percent of the Ph.D.'s in the biosciences entering medical research as independent investigators will enter the medical research as independent investigators (20 percent per annum); the other 40 percent will enter between the 7th and 10th year following award of the Ph.D. degree (10 percent per annum). It is further assumed that a substantial proportion will have had experi-

ence as research assistants and research associates prior to entering the independent investigator pool. It is also recognized that some enter the pool for the first time 20-25-30 years after receipt of Ph.D. degree. Foreign input (Ph.D.'s) is assumed to be constant at 10 percent of the total number of Ph.D.'s in the biosciences entering the medical research manpower pool each year. Foreign input consists of the following components:

- a. U.S. citizens who went abroad to complete their science training for the Sc.D., Ph.D., or equivalent degree who may or may not be U.S. citizens and are now engaged in research in the U.S.
- b. Ph.D.'s trained abroad who are conducting research, whose research expenditures are included in the total national expenditures for medical research either in the government or the industry component. Research expenditures for medical research in the industry component are excluded (due to lead time) from this class is not complete until 1956. From 1956 on, totals are complete except for Ph.D.'s from classes prior to 1947 who go into research subsequent to 10 years after receipt of the Ph.D. degree.
- c. Ph.D.'s trained abroad who are also incomplete prior to 1956. In order to approximate method in the model, foreign entrants are computed at approximately 15 percent of the total for the years 1950-55 when the number shown for U.S. trained Ph.D.'s does not reflect the complete flow for the U.S. supply.

Resources Analysis Section
Office of Program Planning, NIH
January 1962

Appendix Table 7B

Model for Estimating Cumulative Flow of Ph.D.'s in the Biosciences Entering into the Medical Research Manpower Supply from Those Awarded Ph.D. Degrees 1947-67
(Shows Research Input in the Years 1950-1970)

Ph.D. Degrees Awarded Year	Entering Med. Res. Number	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	Diff. Between 1960 & 1970
1947	420	66	131	197	229	262	294	326	326	326	326	326	326	326	326	326	326	326	326	326	326	326	-
1948	552		87	173	260	304	347	391	434	434	434	434	434	434	434	434	434	434	434	434	434	434	-
1949	719			114	228	342	399	455	512	568	568	568	568	568	568	568	568	568	568	568	568	568	-
1950	820				129	258	387	452	517	582	647	647	647	647	647	647	647	647	647	647	647	647	-
1951	916					146				584	657	730	730	730	730	730	730	730	730	730	730	730	-
1952	1018						162	323	438	511	584	657	730	730	730	730	730	730	730	730	730	730	-
1953	1258							200	400	600	701	802	903	1004	1004	1004	1004	1004	1004	1004	1004	1004	202
1954	1258								201	401	602	702	802	903	1003	1003	1003	1003	1003	1003	1003	1003	301
1955	1222								198	395	593	691	789	887	985	985	985	985	985	985	985	985	392
1956	1093									176	352	528	615	702	790	877	877	877	877	877	877	877	325
1957	1251										202	381	468	555	642	730	817	817	817	817	817	817	817
1958	1251											202	381	468	555	642	730	817	817	817	817	817	817
1959	1226												201	197	394	591	690	788	887	985	985	985	1009
1960	1346																						1085
1961	1425																						1157
1962	1545																						1255
1963	1724																						1400
1964	1849																						1501
1965	2030																						1646
1966	2229																						1812
1967	2352																						1912
U.S. Total		66	218	484	846	1312	1881	2585	3386	4259	5154	6085	7045	8032	9033	10066	11154	12326	13583	14941	16422	18026	11941
Foreign Input		11	38	86	151	236	341	472	611	785	954	1132	1315	1505	1697	1898	2110	2339	2586	2852	3144	3460	2328
Total, New Entrants into Medical Research Manpower Supply		77	256	570	997	1548	2222	3057	3997	5044	6108	7217	8360	9537	10730	11964	13264	14665	16169	17793	19566	21486	14269

See annual flow model for notes on source and method.

Appendix Table 8A

Model for Estimating Annual Flow of Pb.D.'s in the Basic Medical Sciences into the Medical Research Manpower Supply from Those Awarded Pb.D. Degrees 1947-67
(Shows Research Input in the Years 1950-70)

Ph.D. Degrees Awarded Year	Entering Medical Residency Number	No.	Year																				Total		Net Increment 1961 - 1970 Total Average	
			1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970			
1947	160	114	29	14	15	21	14																		45	4
1948	239	215	43	43	22	21																			112	11
1949	326	293	59	59	29	29	33	33	33																185	17
1950	362	326	65	65	33	33	33	33	33																232	23
1951	444	400	80	80	80	80	80	80	80																302	30
1952	516	466	89	89	89	89	89	89	89																387	39
1953	596	546	111	111	111	111	111	111	111																462	47
1954	610	549	110	110	110	110	110	110	110																545	55
1955	647	582	116	116	116	116	116	116	116																620	63
1956	560	504	101	101	101	101	101	101	101																702	70
1957	676	608	122	122	122	122	122	122	122																782	78
1958	869	788	150	150	150	150	150	150	150																862	87
1959	926	845	161	161	161	161	161	161	161																956	96
1960	711	640	128	128	128	128	128	128	128																1041	105
1961	794	701	143	143	143	143	143	143	143																1124	114
1962	868	781	171	171	171	171	171	171	171																1248	124
1963	967	870	196	196	196	196	196	196	196																1348	137
1964	1031	968	203	203	203	203	203	203	203																1448	147
1965	1130	1068	226	226	226	226	226	226	226																1566	159
1966	1255	1186	253	253	253	253	253	253	253																1698	173
1967	1329	1196	239	239	239	239	239	239	239																1848	189
U.S. Total			29	72	131	181	240	298	377	432	484	501	535	557	574	587	614	656	714	769	833	915	998	7217	722	
Foreign Input			7	18	33	45	60	75	94	108	121	125	134	139	143	147	153	164	179	192	208	229	250	1804	180	
Total, Net Entrance into Med. Residency Program-Supply			36	90	164	226	300	373	471	540	605	626	669	696	717	734	767	820	893	961	1041	1144	1248	9021	902	

prior to entering the independent investigator pool. It is also recognized that some enter the pool for the first time, 20-25-30 years after receipt of Ph.D. degree.

Foreign input (Ph.D.'s trained in foreign universities) equals 20 percent of the total number of Ph.D.'s in the basic medical sciences entering the medical research manpower pool each year. Foreign input consists of the following components:

a. U.S. citizens who went abroad to complete their science training for the Sc.D., Ph.D., or equivalent degree.

b. Ph.D.'s who received their degree abroad who may or may not be U.S. citizens and are now engaged in research in the U.S.

c. Ph.D.'s trained abroad who are conducting research, whose research expenditures are included in the total national expenditures for

Because the model begins with the graduating class of 1947, input into medical research either in the government or the industry component of research (due to lead time) from this class is not complete until 1956.

th.D. degree. Foreign income into research are also incomplete prior to 194. In order

U.S. trained Ph.D.'s does not reflect the complete flow for the U.S. supply.

Resources Analysis Section

Resources Analysis Section
Office of Program Planning, NIH
January 1962

NOTE ON SOURCE

Source: Ph.D. output 1947-60 from National Academy of Sciences-National Research Council series. Data for years 1947-56 are published in *Doctorate Production in United States Universities, 1936-1956* (NAS-NRC). Data for years 1958 and 1959 are published in *The Science Doctorate, 1958 and 1959* (National Science Foundation, (NSF 60-60)). Data for 1957 and 1960 have been made available by NRC to the National Institutes of Health. Projections 1961-1991-1996-1970 developed by Resources Analysis Section, OPP, NIH. See Appendix Table 17.

NOTES ON METHOD

1. Ninety percent of the Ph.D.'s in the basic medical sciences will enter into medical research as independent investigators at some time during their career.
2. There is a minimal 3-year lag between receipt of the Ph.D., subsequent receipt of a postdoctoral fellowship, and entry into medical research.
3. In developing this model, it has been assumed that 60 percent of the Ph.D.'s in the basic medical sciences entering medical research as independent investigators will do so in the 3 years following postdoctoral training (70 percent per annum); the other 40 percent will enter between 7-10 years following receipt of the Ph.D. degree (10 percent per annum). It is further assumed that 80 percent of the Ph.D.'s will have had experience as research assistants and research associates

Appendix Table 8B

Model for Estimating Cumulative Flow of Ph.D.'s in the Basic Medical Sciences into the Medical Research Manpower Supply from Those Awarded Ph.D. Degrees, 1947-67
(Shows Research Input in the Years 1950-70)

Ph.D. Degrees Awarded Year	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	Difference Between 1970 1960 & 1970
Number	160	239	326	444	556	647	582	504	608	669	711	704	866	1031	1128	1255	1329	90	90	90	90	90	90	90	90	90
%	144	215	326	400	446	549	549	549	549	549	549	549	549	549	549	549	549	549	549	549	549	549	549	549	549	549
No.	29	43	59	89	111	117	117	117	117	117	117	117	117	117	117	117	117	117	117	117	117	117	117	117	117	117
U.S. Total	29	101	232	413	653	951	1328	1760	2244	2745	3280	3837	4411	4997	5612	6268	6982	7751	8584	9499	10497	7217				
Foreign Input	7	25	58	103	163	238	332	430	561	686	820	959	1103	1249	1403	1567	1745	1938	2146	2375	2624	1804				
Total, New Entrants into Medical Research Manpower Supply	36	126	290	516	816	1189	1660	2190	2805	3431	4100	4796	5514	6246	7015	7835	8727	9689	10730	11874	13121	9021				

See annual flow model for notes on source and method.

Appendix Table 9A

Model for Estimating Annual Flow of Ph.D.'s in the Other Biosciences Entering into the Medical Research Manpower Supply from Those Awarded Ph.D. Degrees, 1947-67
(Shows Research Input in the Years 1950 - 1970)

Ph.D. Degree Awarded	Entering Medical Research	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	Total	Average	Net Increment 1961 - 1970
Year	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number
1947	260																								
1948	313																								
1949	393																								
1950	458																								
1951	472																								
1952	520																								
1953	626																								
1954	648																								
1955	575																								
1956	533																								
1957	574																								
1958	582																								
1959	595																								
1960	635																								
1961	631																								
1962	677																								
1963	777																								
1964	818																								
1965	902																								
1966	974																								
1967	1023																								
U.S. Total																									
Foreign Input																									
Total, Entrances into Medical Research Manpower Supply																									

NOTE ON SOURCE

Source: Ph.D. output 1947-60 from National Academy of Sciences-National Research Council series. Data for years 1947-56 are published in Doctorate Production in United States Universities, 1916-1956 (NAS-NRC). Data for years 1958 and 1959 are published in The Science Doctorates of 1958 and 1959, National Science Foundation, (NSF-1960-1) and Doctorate Production in United States Universities, 1958-1959, National Academy of Sciences, National Research Council. Data for years 1961-1970 developed by Resources Analysis Section, OPP, NIH. See Appendix Table 17.

NOTES ON METHOD

1. Ninety percent of the Ph.D.'s in the other biological sciences will engage in research activities; 70 percent will enter into medical research as independent investigators at some time during their career.
2. There is a minimal 3-year lag between receipt of the Ph.D., subsequent receipt of a postdoctoral fellowship, and entry into research.
3. In developing this model, it has been assumed that 60 percent of the Ph.D.'s in the other biological sciences entering medical research will do so in the 3 years following postdoctoral training (20 percent per annum); the other 40 percent will enter between the 7th and 10th year following receipt of the Ph.D. It is assumed that the research experience and substantial proportion will have had experience as research assistants and research associates prior to entering the independent investigator

pool. It is also recognized that some enter the pool for the first time, 20-25-30 years after receipt of Ph.D. degree.

4. Foreign input (Ph.D.'s trained in foreign universities) equals 10 percent of the total number of Ph.D.'s in the other biological sciences entering the medical research pool each year. Foreign input consists of the following components:
 - a. U.S. citizens who went abroad to complete their science training for Sc.D., Ph.D., or equivalent degree.
 - b. Ph.D.'s who received their degree abroad who may or may not be U.S. citizens.
 - c. Ph.D.'s trained abroad who are conducting research, whose research expenditures are included in the total national expenditures for medical research either in the government or the industry component.
5. Research expenditures for medical research in the U.S. from 1950 to 1959 research (base to lead line) from this class is not complete until 1956. From 1956 on, totals are complete except for Ph.D.'s from classes prior to 1947 who go into research subsequent to 10 years after receipt of the Ph.D. degree.
6. Foreign input into research was also incomplete prior to 1956. In order to approximate method in the model, foreign entrants are computed at 10 percent of the total for the year 1950-55, when the number shown for U.S. trained Ph.D.'s does not reflect the complete flow for the U.S. supply.

Appendix Table 9B

Model for Estimating Cumulative Flow of Ph.D.'s in the Other Biosciences Entering into the Medical Research Manpower Supply from Those Awarded Ph.D. Degrees 1947-67
(Shows Research Input in the Years 1950-1970)

Ph.D. Degrees Awarded	Entering Medical Research	Percent	Number	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	Diff. Between 1960 & 1970
1947	260	70	182	37	73	110	128	146	164	182	182	182	182	182	182	182	182	182	182	182	182	182	182	182	182	-
1948	313	70	219		44	87	131	153	175	197	219	219	219	219	219	219	219	219	219	219	219	219	219	219	219	-
1949	393	70	275			55	110	165	193	220	248	275	275	275	275	275	275	275	275	275	275	275	275	275	275	-
1950	458	70	321			64	129	193	225	257	289	321	321	321	321	321	321	321	321	321	321	321	321	321	321	-
1951	472	70	330				66	132	198	241	264	297	330	330	330	330	330	330	330	330	330	330	330	330	330	-
1952	522	70	365					73	146	219	255	292	328	365	365	365	365	365	365	365	365	365	365	365	365	37
1953	640	70	448					89	179	268	313	358	403	448	448	448	448	448	448	448	448	448	448	448	448	90
1954	648	70	456						91	182	273	318	363	409	454	454	454	454	454	454	454	454	454	454	454	136
1955	575	70	403						81	162	243	283	323	363	403	403	403	403	403	403	403	403	403	403	403	160
1956	533	70	373						75	150	225	262	299	336	373	373	373	373	373	373	373	373	373	373	373	223
1957	574	70	402							81	161	242	282	322	362	402	402	402	402	402	402	402	402	402	402	321
1958	582	70	407								81	162	243	284	325	366	407	407	407	407	407	407	407	407	407	407
1959	595	70	417									81	162	243	284	325	366	407	407	407	407	407	407	407	407	417
1960	635	70	445										89	178	267	312	356	401	445	445	445	445	445	445	445	445
1961	631	70	442												88	176	264	309	353	398	442	442	442	442	442	442
1962	677	70	474														191	286	333	380	427	427	427	427	427	427
1963	757	70	530															95	106	106	106	106	106	106	106	424
1964	818	70	573																							424
1965	902	70	631																							402
1966	974	70	682																							378
1967	1023	70	716																							378
																										126
																										136
																										143
U.S. Total				37	117	252	433	659	930	1257	1626	2015	2409	2805	3208	3621	4036	4454	4886	5344	5382	6357	6923	7529	7529	4724
Foreign Input				4	13	28	48	73	103	140	181	224	268	312	356	402	448	495	543	594	648	706	769	836	836	524
New Entrants into Medical Research Manpower Supply				41	130	280	481	732	1033	1397	1807	2239	2677	3117	3564	4023	4484	4949	5429	5938	6480	7063	7692	8365	8365	5248

See annual flow model for notes on source and method.

Appendix Table 10A

Model for Estimating Annual Flow of Ph.D.'s in Psychology into the Medical Research Manpower Supply from Those Awarded Ph.D. Degrees, 1947-67
(Shows Research Input in the Years 1950-1970)

Ph.D. Degrees Awarded Year	Entering Medical Research																			Net Increment 1961-1970						
	Number	Percent	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	Total	Average	
1947	118	50	59	3	5	6	6	12	12	9	6													-	-	
1948	176	50	88		4	8	9	9	18	18	13	9												-	-	
1949	270	50	135			7		13	13	14	27	20	14											-	-	
1950	348	50	174				9	17	17	17	36	35	26	17										24	2	
1951	483	50	242					12	25	24	24	49	48	36	24									73	7	
1952	580	50	290					15	29	29	29	57	58	44	29									147	15	
1953	652	50	326						16	17				65	49	33								216	22	
1954	664	50	332											66	50	33								274	27	
1955	729	50	365											72	73	31	61	62	47	31				263	26	
1956	619	50	310											31	31	31	36	36	73	72	54	36		343	34	
1957	721	50	361											20	20	20	40	40	80	80	60	40		400	40	
1958	799	50	400											18										406	41	
1959	811	50	406																			41		46	46	
1960	761	60	457																		91	68		437	46	
1961	801	60	481																		96	73		433	43	
1962	874	60	524																		96	73		392	39	
1963	980	60	588																		52	52		105	32	
1964	1056	60	634																		59	59		118	32	
1965	1166	60	700																		32	63		63	221	22
1966	1287	60	772																		35	70		70	175	18
1967	1365	60	819																		39	77		116	12	
																					41	41		41	4	
U.S. Total	15260			3	9	21	37	63	101	140	185	226	263	294	324	343	357	374	397	420	459	497	541	593	4305	430

NOTE ON SOURCE

Source: Ph.D. output 1947-1960 from National Academy of Sciences-National Research Council series. Data for years 1947-56 are published in Doctorate Production in United States Universities, 1936-1956 (NAS-NRC). Data for years 1957 and 1959 are published in The Science Doctorates of 1958 and 1959, National Science Foundation, (NSF 60-60). Data for 1957 and 1960 have been made available by NRC to the National Institutes of Health, Projections, 1961-1970, developed by Resources Analysis Section, OPP, NIH. See Appendix table 17.

NOTES ON METHOD

1. Fifty percent of the Ph.D.'s in psychology who graduated between 1947-59 and 60 percent who graduated between 1960-67 will enter into medical

2. Research as independent investigators at some time during their career.
3. There is a minimal 3-year lag between receipt of the Ph.D., subsequent postdoctoral training, and entrance into independent medical research. The Ph.D.'s entering research will be distributed over an eight-year period starting with 5 percent in the first year, 10 percent each in the 2nd, 3rd and 4th years, 20 percent in the 5th and 6th years, 15 percent in the 7th year, and 10 percent in the 8th year.
4. Because the model begins at the graduating class of 1947, input into research (due to lead time) from this class is complete, until 1957. From 1957 on, totals are complete only for Ph.D.'s from education prior to 1948 who enter research prior to 11 years after graduation.
5. The model makes no estimate for foreign input because, thus far, this source has been negligible for psychology in contrast to substantial numbers of foreign-trained M.D.'s and Ph.D.'s in the biosciences.

Appendix Table IOB

Model for Estimating Cumulative Flow of Ph.D.'s in Psychology into the Medical Research Manpower Supply from Those Awarded Ph.D. Degrees, 1947-67
(Shows Research Input in the Years 1950-1970)

Ph.D. Degrees Awarded Year	Number	Entering Medical Research																Diff.							
		Percent	Number	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1960-1970
1947	118		50	59	3	8	14	20	32	44	53	59	59	59	59	59	59	59	59	59	59	59	59	59	-
1948	176		50	88																					-
1949	270		50	135																					-
1950	348		50	174																					-
1951	483		50	242																					24
1952	580		50	290																					73
1953	652		50	326																					147
1954	664		50	332																					216
1955	729		50	365																					274
1956	619		50	310																					263
1957	721		50	361																					343
1958	799		50	400																					400
1959	811		50	406																					406
1960	761		60	457																					457
1961	801		60	481																					433
1962	874		60	524																					392
1963	980		60	588																					324
1964	1056		60	634																					221
1965	1166		60	700																					175
1966	1287		60	772																					41
1967	1365		60	819																					41
U.S. Total																									
	15260		7635	3	12	33	70	133	234	374	559	785	1048	1342	1666	2009	2366	2740	3137	3557	4016	4513	5054	5647	4305

See annual flow model for notes on source and method.

Resources Analysis Section
Office of Program Planning, NIH
January 1962

Appendix Table 11

Distribution of Physicians by Type of Activity
Showing Percent Change, 1949 and 1959

Type of activity	1949	1959	Percent change
All physicians	<u>201,277</u>	<u>236,089</u>	<u>+ 17.2</u>
Active non-Federal physicians			
Private practice	<u>150,417</u>	<u>160,592</u>	<u>+ 6.8</u>
General practice and part-time specialty	95,526	81,957	- 16.6
Full-time specialty	54,891	78,635	+ 43.3
Hospital service	24,887	39,730	+ 59.6
Full-time research, teaching, administration or public health	3,737	7,931	+112.2
Federal Government service	12,536	17,519	+ 39.7
Not in medical practice	9,700	10,317	+ 6.4

SOURCE: Health Manpower Source Book, PHS Publication No. 263, section 10, Table 1, p. 2, 1960.

Resources Analysis Section
Office of Program Planning, NIH
January 1962

Appendix Table 12

Ph.D.'s Awarded in the Sciences by Field, 1950-1960,
and Estimated Output, 1961-1967

Field	Total 1950- 1967	Years											1961- c/ 1967
		1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	
Total sciences a/	119,464	4,317	4,636	4,866	5,225	5,370	5,536	5,140	5,583	5,768	6,108	6,515	60,400
Biosciences	25,812	820	916	1,018	1,258	1,258	1,222	1,093	1,250	1,251	1,226	1,346	13,154
Basic medical sciences	13,795	362	444	496	618	610	647	560	676	669	631	710	7,372
Other biosciences	12,017	458	472	522	640	648	575	533	574	582	595	636	5,782
Mathematics, physical science, & engineering	56,188	2,246	2,474	2,503	2,486	2,513	2,585	2,421	2,504	2,552	2,825	3,064	28,015
Mathematics	5,835	174	204	204	226	247	243	226	225	236	301	309	3,240
Chemistry	21,130	1,051	1,035	1,062	1,006	1,018	1,009	979	1,041	956	1,062	1,106	9,805
Physics & astronomy	11,221	422	501	519	523	527	506	484	463	505	522	574	5,675
Engineering	13,820	469	586	569	565	560	648	576	590	658	705	824	7,070
All other	4,182	130	148	149	166	161	179	156	185	197	235	251	2,225
Social & behavioral sciences a/ Psychology	31,281	970	1,185	1,265	1,400	1,499	1,608	1,458	1,457	1,634	1,662	1,677	15,466
Sociology & anthropology- b/	14,676	348	483	580	652	664	729	619	721	779	811	761	7,529
All other	4,468	173	189	182	217	250	243	227	185	246	245	232	2,079
	12,137	449	513	503	531	585	636	612	551	609	606	684	5,858
Other science fields	6,183	281	61	80	81	100	121	168	372	331	395	428	3,765

SOURCE: 1950-1956 data - National Research Council, Doctorate Production in United States Universities, 1936-1956, publication 582, pp 6-7; 1957-1960 data supplied by National Research Council; 1961-1967 projections estimated by National Institutes of Health.

a/ National Science Foundation 1970 projection for Ph.D.'s in the sciences excludes history. To insure comparability with the NSF coverage of science Ph.D.'s, history has been omitted from the social sciences, although normally included in social science doctorate data published by the National Research Council and the Office of Education.

b/ Includes archaeology, from 1950 through 1960.

c/ See appendix table 17 for year-by-year detail and note on method.

Resources Analysis Section
Office of Program Planning, NIH
January 1962

Appendix Table 13

Projections of Master's Degrees in Nursing, Social Work
and Public Health, 1961-1970

Year	Field			
	Total	Nursing	Social work	Public health
Total 1961-70	44,499	8,050	29,643	6,806
1961	3,515	636	2,249	630
1962	3,717	674	2,402	641
1963	3,907	711	2,544	652
1964	4,103	749	2,691	663
1965	4,310	786	2,850	674
1966	4,517	824	3,008	685
1967	4,724	861	3,166	697
1968	4,965	899	3,357	709
1969	5,233	936	3,576	721
1970	5,508	974	3,800	734

SOURCE: National Institutes of Health. Projections developed by Resources Analysis Section, Office of Program Planning, NIH, based upon 1950-60 data (published by the Office of Education, DHEW and Statistics in Social Work Education, annual issues, Council of Social Work Education). Projections are based upon the assumption that the percentage increase of the decade 1950-60 will continue to 1970 with appropriate increases in the intervening years.

Resources Analysis Section
Office of Program Planning, NIH
January 1962

Appendix Table 14

Output of M.D.'s from U.S. Schools, 1947-1960
with Projections for 1961-1970

First-year enrollment		Year of graduation	Number receiving M.D. degrees	Percent of entering students graduating four years later
Academic year	No. of students			
1946-47	6564	1950	5553	84.6
1947-48	6487	1951	6135	94.6
1948-49	6688	1952	6080	90.9
1949-50	7042	1953	6668	94.7
1950-51	7177	1954	6861	95.6
1951-52	7436	1955	6977	93.8
1952-53	7425	1956	6845	92.2
1953-54	7449	1957	6796	91.2
1954-55	7576	1958	6861	90.6
1955-56	7686	1959	6860	89.3
1956-57	8014	1960	7081	88.3
1957-58	8030	1961	6994	87.1
1958-59	8128	1962	7150	88.0
1959-60	8173	1963	7225	88.4
1960-61	8298	1964	7350	88.6
1961-62	8422	1965	7500	89.0
1962-63	8548	1966	7600	88.9
1963-64	8676	1967	7700	88.7
1964-65	8806	1968	7800	88.6
1965-66	8938	1969	7900	88.4
1966-67	9072	1970	8000	88.2
Total 1961-1970	////	////	75,219	////

SOURCE: Enrollment and output data, 1946-1961, from JAMA 178:647 (table 14); 1961. Projections for 1965 and 1970 from Physicians for a Growing America, PHS Publication 709, p. 3 (table 2), 1959. Projections for intervening years interpolated by National Institutes of Health.

NOTE ON METHOD

Projections for 1965 and 1970 are from Physicians for a Growing America. Projections for 1962-64 and 1966-69 have been interpolated by the National Institutes of Health based on first-year enrollments increasing 1.5 percent annually following the pattern of the class of 1960-61 over the class of 1959-60.

Resources Analysis Section
Office of Program Planning, NIH
January, 1962

Appendix Table 15

Graduates of U. S. Medical Schools and
U. S. Graduates of Foreign Medical Schools
Receiving U. S. Licenses, 1950-1960

Year	No. of U. S. medical schools	No. of graduates of U. S. medical schools	Initial U. S. licenses issued to American graduates of foreign medical schools
1950-54	79	31,297	99 <u>a/</u>
1955	80	6,977	89 <u>a/</u>
1956	81	6,845	103 <u>a/</u>
1957	82	6,796	212
1958	85	6,861	284
1959	85	6,860	366
1960	85	7,081	386
Ratio 1960/1955 ////		1.01	3.75

a/ Data not available for New York and Pennsylvania.

SOURCES:

1. Graduates of U.S. medical schools data from JAMA 178:647 (table 14), 1961.
2. Initial U. S. licenses issued to American graduates of foreign medical schools data from JAMA 178:605 (table 16), 1961.

Resources Analysis Section
Office of Program Planning, NIH
January 1962

Appendix Table 16

Estimated Output of M.D.'s from U.S. Medical Schools and Additions to the U. S. Supply from Graduates of Foreign Medical Schools, 1961-1970

Year	Estimated addition to U.S. supply of M.D.'s	New U.S. medical school graduates	Foreign medical school graduates
TOTAL			
1961-70	94,024	75,219	18,805
1961	8,742	6,994	1,748
1962	8,938	7,150	1,788
1963	9,031	7,225	1,806
1964	9,188	7,350	1,838
1965	9,375	7,500	1,875
1966	9,500	7,600	1,900
1967	9,625	7,700	1,925
1968	9,750	7,800	1,950
1969	9,875	7,900	1,975
1970	10,000	8,000	2,000

SOURCE: New U.S. medical school graduates for 1961 from JAMA 178:647 (table 14), 1961. Projections for 1965 and 1970 from Physicians for a Growing America, PHS Publication No. 709, p. 3 (table 2), 1959. Projections for intervening years interpolated by National Institutes of Health. Graduates of foreign medical schools 1950-1960 from JAMA 178:180, 1961.

Notes on Method

1. Projections of new U.S. medical school graduates for 1965 and 1970 are taken from Physicians for a Growing America. Projections for 1962-64 and 1966-69 have been interpolated by the National Institutes of Health based on first-year enrollments increasing 1.5 percent annually following the pattern of the class of 1960-61 over the class of 1959-60.
2. Foreign M.D. input is estimated at 20 percent of total new additions to the U.S. supply.

Resources Analysis Section
Office of Program Planning, NIH
January 1962

Appendix Table 17

Projections of Ph.D. Output in the Sciences 1961-1970

Field	Total 1961- 1970	Years									
		1961	1962	1963	1964	1965	1966	1967	1968	1969	1970
Total sciences^{a/}	96,300	7,000	7,400	8,000	8,500	9,200	9,900	10,400	11,000	11,900	13,000
Biosciences	21,538	1,425	1,545	1,724	1,849	2,030	2,229	2,352	2,534	2,784	3,066
Basic medical sciences	12,120	794	868	967	1,031	1,128	1,255	1,329	1,431	1,576	1,741
Other biosciences	9,418	631	677	757	818	902	974	1,023	1,103	1,208	1,325
Mathematics, physical science, and engineering	43,920	3,365	3,515	3,730	3,945	4,235	4,500	4,725	4,920	5,265	5,720
Mathematics	5,410	340	375	410	460	505	550	600	645	725	800
Chemistry	15,055	1,230	1,270	1,330	1,385	1,465	1,545	1,580	1,645	1,740	1,865
Physics	9,110	655	695	745	800	865	935	980	1,050	1,135	1,250
Engineering	11,275	825	870	930	995	1,075	1,160	1,215	1,290	1,390	1,525
All other	3,070	315	305	315	305	325	310	350	290	275	280
Social & behavioral sciences ^{a/}	25,072	1,730	1,850	2,036	2,171	2,375	2,586	2,718	2,916	3,186	3,504
Psychology	12,445	801	874	980	1,056	1,166	1,287	1,365	1,478	1,632	1,806
Sociology & anthropology	3,295	241	256	278	293	316	340	355	375	404	437
All other	9,332	688	720	778	822	893	959	998	1,063	1,150	1,261
Other science fields	5,770	480	490	510	535	560	585	605	630	665	710

SOURCE: 1970 total Ph.D.'s - National Science Foundation, Investing in Scientific Progress, NSF 61-27, 1961.
Year-by-year projections and estimates by field - National Institutes of Health.

Note on Method - see next page.

^{a/} National Science Foundation 1970 projection for Ph.D.'s in the Sciences excludes history. To insure comparability with the NSF coverage of science Ph.D.'s, history has been omitted from the social sciences, although normally included in social science doctorate data published by the National Research Council and the Office of Education.

Resources Analysis Section
Office of Program Planning, NIH
January 1962

Note on Method

The National Science Foundation projection of 13,000 Ph.D.'s in the sciences in 1970 is used as the terminal figure. See Investing in Scientific Progress, p. 13, for NSF discussion of conservative character of this projection.

Projections shown in Appendix Table 17, for the Biosciences and the Social and the Behavioral Sciences have been developed by the National Institutes of Health. These projections represent the calculation of each of the major component disciplines (see Appendix Table 18) within these fields as a percentage of estimated total doctoral output; the latter figure in turn was derived from a trend line fitted to doctoral output 1950-60 and projected to a 1970 total of 21,000 Ph.D.'s; total Ph.D.'s are based upon the rising percentage of Ph.D.'s against a rising population base in the Ph.D. age group. Specifically, the component discipline percentages were arrived at in the following manner:

Biosciences. Based upon a steady annual rise of 0.1 percent over the decade as a proportion of all doctorates.

Basic medical sciences. In each sub-field a five-year moving average (1956-60) of the percentage of total bioscience doctorates carried forward to 1970, with the exception of the biophysics percentage doubling and genetics percentage increasing 50 percent over the decade.

Other biosciences. Each sub-field represents a five-year (1956-60) moving average of the percentage of all bioscience doctorates carried forward to 1970; with the exception of zoology decreasing 2.9 percent over the decade to reflect a pronounced downward trend.

Social and behavioral sciences. Maintains same relative position over decade in relation to total doctorate production. Psychology. Projections are based upon an increase of one percent in the proportion of Ph.D.'s in psychology to total Ph.D. output from 1960 to 1970, from 7.6 percent to 8.6 percent, with proportionate increases in the intervening years. Sociology and anthropology increase absolutely as a percentage increase over the next decade equivalent to the percentage increase over the decade 1950-1960.

Mathematics, physical sciences, engineering and other science fields. In the aggregate, estimates for these fields are residual figures obtained by subtracting the year-by-year projections for the biosciences and social and behavioral sciences from the year-by-year projection for all science Ph.D.'s derived by approximating the compound rate of growth necessary to reach the NSF projection of 13,000 doctorates in the sciences in 1970. If the method used in developing year-by-year projections for the biosciences and the social and behavioral sciences had been applied to all other science fields, the total projection for 1970 would have exceeded 14,000 Ph.D.'s in the sciences, with all of the increment being distributed among these other science fields. Hence, the figures shown for mathematics, physical sciences, engineering and all other science fields must be regarded as suggestive rather than definitive projections.

Within this context, the totals shown for the mathematics, the physical sciences, engineering, and all other science fields represent a projected decrease in the proportion of these fields to total science doctorates adjusted to conform to the 13,000 end position for 1970. Increases in the several fields are variable based on recent trends: Mathematics and statistics increase at a rate about double the physical sciences and engineering; within the physical sciences, physics and astronomy increase at a slightly faster rate than the group as a whole while chemistry projections reflect about half the proportionate increase of physics and mathematics combined due to the fact that chemistry in the 50's represented a declining proportion of total science Ph.D.'s; engineering increases parallel those of all science fields; for all other science fields, trends of the 1951-1960 decade have been extended to 1970.

Resources Analysis Section
Office of Program Planning, NIH
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Appendix Table 18

Projection of Ph.D. Output in the Biosciences, by Discipline, 1961-1970

Field	Years										
	Total 1961- 1970	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970
All biosciences	<u>21538</u>	<u>1425</u>	<u>1545</u>	<u>1724</u>	<u>1849</u>	<u>2030</u>	<u>2229</u>	<u>2352</u>	<u>2534</u>	<u>2784</u>	<u>3066</u>
Basic medical sciences	<u>12120</u>	<u>794</u>	<u>868</u>	<u>967</u>	<u>1031</u>	<u>1128</u>	<u>1255</u>	<u>1329</u>	<u>1431</u>	<u>1576</u>	<u>1741</u>
Anatomy	582	40	40	47	50	55	60	64	68	75	83
Biochemistry	4604	305	335	371	396	430	477	503	542	593	652
Biophysics	648	28	34	40	46	55	67	75	86	100	117
Microbiology	3054	204	223	248	259	286	317	334	358	393	432
Pathology	239	17	17	19	20	22	25	26	28	31	34
Pharmacology	788	58	57	64	68	73	82	85	91	100	110
Physiology	2205	142	162	178	192	207	227	242	258	284	313
Other biosciences	<u>9418</u>	<u>631</u>	<u>677</u>	<u>757</u>	<u>818</u>	<u>902</u>	<u>974</u>	<u>1023</u>	<u>1103</u>	<u>1208</u>	<u>1325</u>
Botany	1779	123	128	140	154	169	185	193	208	228	251
Entomology	1425	92	104	116	122	136	147	155	167	184	202
Genetics	1624	90	97	114	127	146	165	181	203	231	270
Plant pathology	1169	75	85	95	102	112	120	127	137	150	166
Zoology	2579	198	206	223	236	260	270	275	289	306	316
Other	842	53	57	69	77	79	87	92	99	109	120

SOURCE: National Institutes of Health.

Notes on Method

1. Projection of Ph.D. output, developed by the National Institutes of Health, assume a steady annual rise of bioscience doctorates (0.1%) as a proportion of all doctorates over the decade 1961-1970 (see Appendix Table 17).
2. Projections for individual disciplines within the biosciences take into account their respective Ph.D. output trends, 1950-1960, and are based upon a five-year moving average (1956-1960) of percentage of each discipline's output to total science doctorates carried forward to 1970.

In two of the smaller disciplines where sharp percentage increases in enrollment have occurred, judgmental estimates have been made for:

- (1) biophysics which is doubled over the decade, and
- (2) genetics which is increased by fifty percent over the decade.

Taking into account long-term trends, the projection for zoology assumes a continuing decrease of 2.9 percent over the 1961-1970 decade.

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